Amidon (R. W.)

A NEW STUDY OF CEREBRAL CORTICAL LOCALIZATION. THE EFFECT OF WILLED MUSCULAR MOVEMENTS ON THE TEMPERATURE OF THE HEAD.

THE ESSAY TO WHICH WAS AWARDED THE PRIZE OF THE ALUMNI ASSOCIATION OF THE COLLEGE OF PHYSICIANS AND SURGEONS, NEW YORK, MARCH 12TH, 1880.

BY

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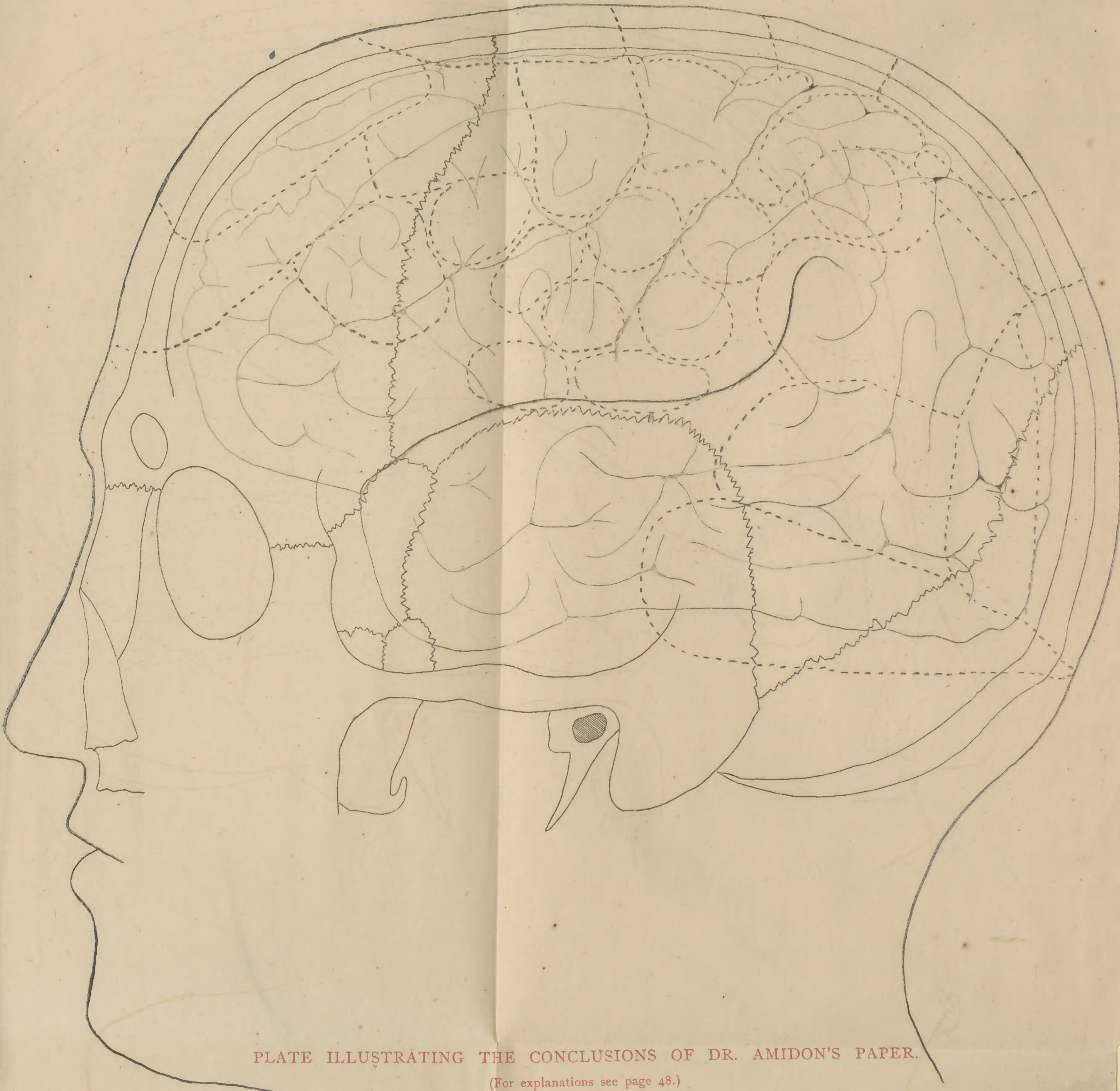

PLATE ILLUSTRATING THE CONCLUSIONS OF DR. AMIDON'S PAPER.

(For explanations see page 48.)

THE EFFECT OF WILLED MUSCULAR MOVEMENTS ON THE TEMPERATURE OF THE HEAD: NEW STUDY OF CEREBRAL CORTICAL LOCALIZATION.

The essay to which was awarded the prize of the Alumni Association of the College of Physicians and Surgeons, New York, March 12th, 1880.

By R. W. AMIDON, A.M., M.D.

ASSISTANT AT THE CLINIC FOR DISEASES OF THE NERVOUS SYSTEM, COLLEGE OF PHYSICIANS AND SURGEONS, NEW YORK.

Introduction.—As a preface to our investigations, and for their better comprehension, three rather modern branches of medical science must be briefly reviewed, viz., Cranio-Cerebral Topography, Cerebral Cortical Localization, and Cerebral Thermometry.

CRANIO-CEREBRAL TOPOGRAPHY.*

Although the grosser relationships between the brain and skull have for a long time attracted attention, it is only within the last few years that accurate data have been forthcoming as to the exact relations individual convolutions bear to their surrounding envelopes. Of the many methods pursued in studying cranio-cerebral topography, none insures such scientific accuracy and is so simple as that invented by Broca and used by many others.

The method consisted in drilling holes in the skull at fix-

* See Bibliography.

ed points, inserting wooden pegs in the brain through these holes, and then removing the calvarium and dura mater. The pegs remaining imbedded in the cortex will show with exactitude the relations of direction and distance between the convolutions and points on the exterior of the skull.

The chapter in cranio-cerebral topography, which will be found of most utility for clinical and experimental purposes, is the part dealing with the relations borne by individual convolutions, not to the denuded skull, but to the external landmarks demonstrable on the living head.

To this part special attention will be paid, the facts being chiefly drawn from Broca, Féré and Turner, quoted also extensively by Seguin.*

To make all observations uniform, the head must have a constant position. This position is that which is assumed by a skull, without the inferior maxilla, resting on its alveolar processes and occipital bone. This is called the alveolo-condyloid plane, and forms the basis for all future measurements. A perpendicular from this line passing through the external auditory meatus intersects the vertex at a point called the bregma. This is called the auriculo-bregmatic line. The most important landmark in the brain is the fissure of Rolando. Its upper extremity lies 4.5 centimetres behind the bregma (Broca, Féré, etc.). Its lower extremity falls about .5 centimetres behind the auriculo-bregmatic line, and a little above a line Féré draws through the head parallel to the basal plane, passing through the apex of the lambdoid suture and the superciliary ridge of the frontal bone. (See Fig. 1.)

This would bring the lower end of the fissure of Rolando about 6 centimetres above and a little behind the external auditory canal.

Having thus located the fissure of Rolando enables us

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* See Bibliography.

to map out the neighboring convolutions, which are to-day held to be of the greatest importance, as they are supposed to contain the psycho-motor centres of the opposite half of the head, body and extremities.

The ascending parietal convolution will, of course, underlie the surface of the head just behind this region, while the ascending frontal is just in front.

The first or superior frontal convolution will be found commencing about 2.5 centimetres behind the bregma, and passing forward near the median line toward the orbit. The second frontal convolution will occupy a similar but more lateral position, while the third frontal convolution lies wholly in front of the auriculo-bregmatic line, and on a plane 5 centimetres above the external auditory meatus. Its folded or central part is about 2.5 centimetres in front of the auriculo-bregmatic line, or about 2 centimetres behind the external angular process of the frontal bone.

The tip of the sphenoidal lobe is 1 cm. behind the external angular process of the frontal bone, hence at this point the fissure of Sylvius commences.

The middle or horizontal part of the fissure coincides pretty nearly with the squamo-parietal suture, and hence falls near the fronto-lambdoidal line. The termination of the fissure is in the lower posterior parietal region, and this would bring the supra-marginal convolution under the parietal eminence (Turner) and the angular gyrus below and a little behind the same.

The occipital fissure varies very little from the commencement of the lambdoid suture, a point pretty easily made out in most heads. The relations of the fissure of Rolando to the antero-posterior diameter of the brain as determined by Féré are interesting. Its superior extremity is in the average 11.1 centimetres from the frontal extremity (range

from 9.5–12.5 cm.) and 4.9 cm. from the occipital extremity.

The lower extremity of the fissure is 7.1 centimetres from the frontal extremities (6.4–8.2 cm.) and 8.9 cm. (7.2–10) from the occipital extremity of the brain.

With such data as are contained in the above paragraphs at our disposal we can see the convolutions, so to speak, through the scalp, skull, and meninges.

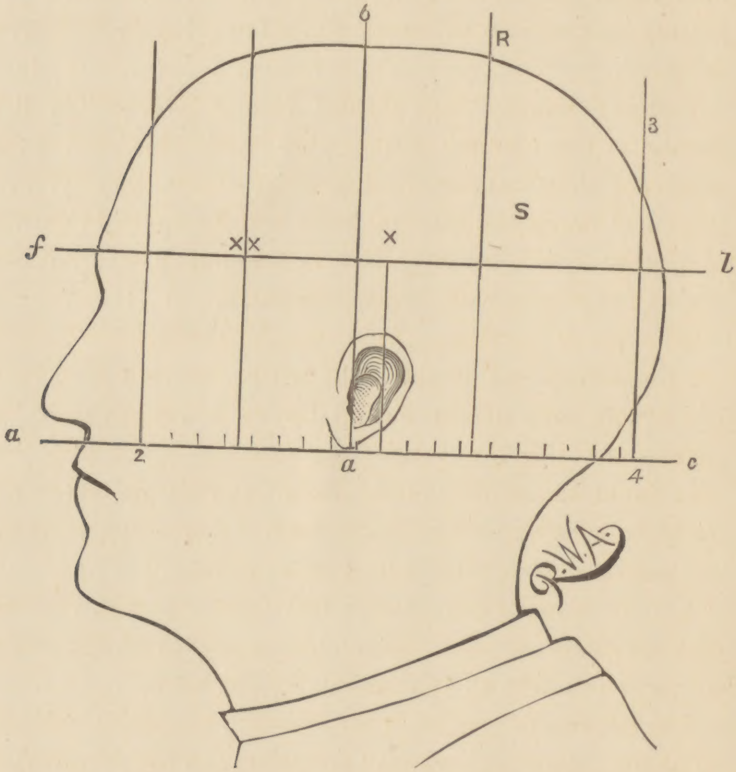

FIG. 1.—Outline of head, on which most of author's experiments were performed, reduced one-third, on which a modified system of Féré's lines are drawn. *A C*, alveolo-condyloid line; *A B*, auriculo-bregmatic line; *F L*, fronto-lambdoidal line; 1, 2, frontal limit; 3, 4, occipital limit of the brain. *R*, posterior extremity of the fissure of Rolando; *X*, anterior extremity, same; *XX*, location of the middle fold of the third frontal convolution, a little below and in front of which lies the tip of the sphenoidal lobe; S, the posterior extremity of the fissure of Sylvius; and the intersection of the lines 3, 4, and *F L* locates the occipital fissure.

CEREBRAL CORTICAL LOCALIZATION.*

To epitomize the present state of our knowledge on this subject, is indeed a difficult task.

For a branch of medicine which has been so short a time the subject of scientific investigation, its strides have been enormous, and its literature has become exceedingly voluminous. Our knowledge is based on two sets of facts, viz.: experimentation on living inferior animals, and close observation of pathological conditions (traumatisms, neoplasms, vascular disturbances, atrophies, etc.,) in the human subject.

Ferrier * Hitsig,* and Munk,* have, with a careful comparison of the relative anatomy of the two, transferred the results of their conclusive experiments from the brains of dogs and monkeys to that of man, and have laid out a map of psycho-motor centres which is now supported by a vast amount of clinico-pathological evidence.

In spite of numerous negative and contradictory facts, most observers will to-day hold to the assertion that there is a certain area of the human cortex which contains the psycho-motor centres for the opposite half of the body, and that there are certain other areas indefinite in extent and position, which are thought to possess a sensory or psychical function, or at least no motor attributes.

Let us now briefly review the facts at our disposal, gleaned from all authorities. A statement of the rather conservative view of localization is as follows:

The pre-frontal region is considered a psychical area, destructive lesions in animals and man causing no paralysis (?) but being often accompanied by changes of disposition and various morbid mental states. At the junction of the fissure of Rolando, and the superior longitudinal fissure, the angle in front holds centres for the upper, the angle behind centres for the lower extremity.

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* See Bibliography.

Lower down on the two ascending convolutions are centres for complex movements of the forearm, lower still (reaching the fissure of Sylvius) is the facial centre; anterior to which, and lower still on the third frontal and deeper gyri is the tongue and speech centre. The angular gyri or inferior parietal lobule are supposed to have some connection with the vision and ocular movements, while the rest of the cortex has, according to most accepted authorities, no motor function, but is the seat of general and special sensi-

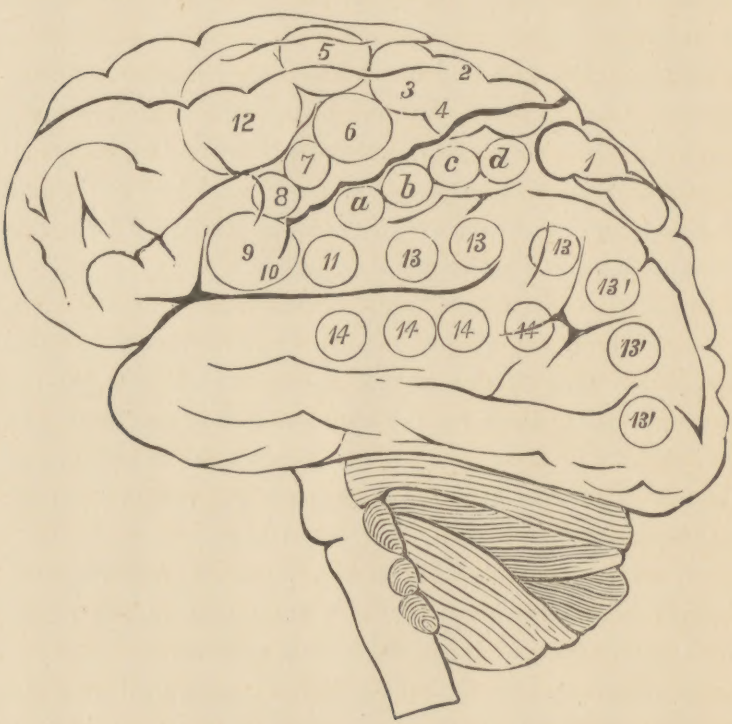

FIG. 2.—Location of centres in the human brain according to Ferrier.
1, centres for opposite leg and foot (locomotion.) 2, 3 and 4, for complex movements of the arms and legs. 5, for extension forward of arm and hand. 6, for hand and forearm, chiefly biceps, supination of hand and flexion of the forearm. 7 and 8, for elevators and depressors of the mouth. 9 and 10, for lips and tongue, as in articulation. 11, for platysma and retraction of angle of the mouth. 12, for lateral movements of head and eyes, elevation of eyelids and dilatation of the pupil. *a*, *b*, *c*, *d*, for hand and wrist. 13 and 13′ for vision. 14, hearing.

bility, viz.: centre for hearing just below that of vision, on the posterior part of the superior temporal lobule; centre for smell in the gyrus uncinatus or subiculum cornu ammonis, and near it a taste centre. Touch is also supposed to occupy a centre at the base, and visceral sensations are thought to lie in the occipital lobe.

An analytical, but more complex—and according to some, fanciful location of motor centres, is given by Ferrier.

He endeavors to make the motor area larger, and attempts analysis of centres into centres for particular movements or muscle groups. That his motor area is not too large, nay, not large enough, and that his subdivision of motor centres is *not* fanciful, will be the burden of proof of the last and original part of this paper. In justice to him I insert his diagram and description in full.

CEREBRAL THERMOMETRY.*

Davy,* pp. 286 and 288, expresses himself surprised to find the temperature of the brain in decapitated animals lower than other parts, even the rectum. His mode of procedure was to thrust the thermometer through the foramen magnum of decapitated animals into the different parts of the encephalon. He found that the temperature of the anterior region of the brain was lower than the posterior; the superficial lower than the deep substance, and all considerably lower than that of the viscera and rectum. On p. 326, while enumerating in detail his investigations in post mortem temperatures in human subjects, dying from various causes, while taking temperatures in the heart, blood, stomach, liver, rectum, etc., in many cases he takes the temperature of the cerebral mass and finds it 8°—10° F.! lower than in the other organs. These results are rather surprising to us who have naturally considered the brain as

* See Bibliography.

particularly well-warmed. Do not his experiments rather show that the brain quickly loses its heat by conduction and radiation?

Lombard * in his first experiments (1867), used a thermo-electric apparatus of such delicacy that a variation of less than $\frac{1}{1000}$° F. was distinctly shown. One pile was attached to the head, while a second was applied to some peripheral part, as the thigh.

Even when at rest there were constant variations (ups and downs) in the temperature, but when his attention was aroused by anything there would be a rise of temperature in the head and a fall in the legs. In reading a stupid book there was a small rise, in reading an interesting one there was a marked rise, while reading aloud caused a still greater rise in the cephalic temperature. (This he considers not due to muscular effort.) A few minutes' recitation caused a much greater rise than several hours of deep thought. He obtained most marked results with the pile, just above the occipital protuberance. His greatest rise was $\frac{1}{20}$° C., while there was sometimes a fall of ¼° C.

In his second experiments * (1878), he tried both ordinary surface thermometers and his thermo-electric apparatus, and concludes that the former are not accurate because it is impossible with them sufficiently to compress the skin to produce a local anæmia which, after Schiff's criticism,† he considers essential to accuracy.

He considers also that there is almost always an inequality in the temperature of the two sides of the head, but thinks the higher temperature is as apt to be on one side as the other.

Lombard's last work † (1879), still on mental states, embody the results of sixty thousand experiments. These

* See Bibliography.

† See p. 126.

demonstrate that small elevations of temperature (hundredths of a degree C. and F.), result from intellectual and emotional excitement.

Schiff's * experiments were carefully made and extremely interesting. The first series were made on dogs and other animals, in whom artificial respiration had to be kept up on account of the paralyzing effect of the curare administered to render the animals quiet.

In the skulls of animals thus quieted he drilled holes and plunged his thermo-electric needles directly into the brain, making the points of puncture on the two sides as symmetrical as possible. These elements he connected by wires to a galvanometric mirror apparatus, and thus, by oscillations of the mirror, to one side or the other, showing a greater rise in one hemisphere than in the other. Then, having the animal quiet and waiting till the galvanometric mirror was at rest, he gently irritated one of the extremities of the animal (by touching, pinching, or even galvanization of the sciatic). Immediately there was a deviation of the needle, which generally showed a greater rise of temperature on the hemisphere of the same side as the peripheral irritation.

He found the greater rise took place in the mid-parietal region, but does not state its exact amount.

Dissatisfied with the experiments on animals under curare he tried morphine as a quieter, but finding, in the brains of animals thus drugged, spontaneous fluctuations of temperature, he tried alcohol subcutaneously, and thus secured immobilization without stopping respiration.

Still not satisfied, he trephined dogs, rabbits and guinea-pigs, inserted his needles, and then allowed the animals sev-

* See Bibliography.

eral days in which to recuperate, and then repeated his experiments on the effect of sensory impressions while the animals slept.

The result of these experiments was the same as that of the former. He also noticed slight fluctuations under the stimulus of the special senses of hearing, smell and sight.

His third series of experiments were on chickens, whose movements were mechanically restrained. Here he obtains similar results in irritation of the general or special senses.

In all his animals, he finds a psychical excitation causes the greatest fluctuations. Hence, in exciting a cat by the exhibition of tempting food, he gets a most marked rise, 18 degrees (?)* He thinks the rise is due to the activity of the nervous elements, not to increased vascularity. He criticises Lombard, pp. 460, 461, whose surface temperatures are greater than his own taken in the brain itself. He also asserts that variations in external temperature cease after section of the cervical sympathetic.

Broca's † experiments with the surface thermometer are more valuable. In his physiological experiments he found the average temperature of the left side of the head a trifle higher than that of the right.

In his pathological cases he found a rise of 2.5° C. over an acute softening, a rise of .4° C. in the left frontal, a rise of 1.7° C. in the left occipital, and a fall of .5° C. in the left temporal region in a case of right hemiplegia with aphasia, and in a case of embolism a fall of 4° over the embolic area.

More recently,† Broca has noticed a fall of 1.° C. in the left frontal, of 1.5° C. in the left temporal, and a smaller fall in the left occipital region in a case of hemiplegia with

* Galvano metricocale.

† See Bibliography.

aphasia, due to embolism or thrombosis. He has also found a lowering of from 5° to 8° on the side of the head opposite the contraction of torticollis or wry neck.

The interesting investigations of Gray * are still fresh in our minds. He, besides further demonstrating the fact that when at rest the temperature of the left hemisphere is the higher, finds in one case after 10 minutes' reading, a rise of .50° F. in the right parietal region, in another a rise of .75° in the left parietal, and .50° in the right frontal region.

In a person after delivering a lecture, he found a fall of 1.67° F. in the left frontal and a rise of 2.5° F. in the left parietal region, while in the right frontal there was a rise of .67° F., in the right parietal a rise of 1.°, and of 2.5° at the right occipital, making a rise of .25° for the whole head—a rise of .98° for the left side, and a fall of .28° for the right.

In a second subject he found, after lecturing, a fall of .25° in the left frontal, 2.° in the left occipital, and a rise of .5° in the left parietal region, in the right frontal a rise of 1.°, and in the right occipital region a fall of .25°. Thus the left side showed an elevation of .69°, while the average rise of the whole head was 1.17° F.

He was also enabled to locate a tumor of the brain by finding a local rise of temperature.

Mills * noticed a small rise, .3° F., over a tumor of the frontal lobe, and also a rise over the right frontal lobe where a tumor existed at the base near that point.

Maragliano and Seppilli * have made many observations on the cerebral temperatures in the sane and insane.†

The highest temperature in the latter class was found in a case of furious mania, where the thermometer indicated 36.9° C., and in other forms of insanity lower temperatures, the lowest being in simple dementia, 36° C.

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* See Bibliography.

† The following account is compiled from the two translations.

In all mental diseases the occipital lobes have a lower temperature. The temperature of the frontal lobes is higher in mania, in simple lypemania and dementia.

In progressive paralysis and lypemania agitata the parietal temperatures are higher.

They find the temperature of the two sides almost equal, and bearing a certain ratio to the variations of body temperature.

Their temperatures in sane persons are higher than those of Broca and Gray, for the simple reason that their observations were made in summer, while the latter experimented in winter time.

Mary Putnam Jacobi,* in a case of tubercular meningitis in a child, found an elevation of 3.29° F. above the normal in the right frontal region, when there was a softening of the first part of the first frontal convolution on that side, and also a rise of 6°–7°, F., above the normal, in both occipital stations, where there was found marked tuberculous inflammations of the pia mater, especially under the cerebellum.

THE INITIAL EXPERIMENT AND ITS DEDUCTIONS.

In the summer of 1879 it occurred to the writer that excessive use of a peripheral part (group of muscles) might generate sufficient heat in the cortical centre for that part to manifest itself to surface thermometers placed on the scalp. To test this the surface thermometers were arranged in a strap passing over the vertex, where the center for the arm was thought to be, and after remaining on for fifteen minutes, the temperatures were recorded, and then violent flexion and extension of the right forearm was kept up for ten minutes, and the temperatures were again taken down, with the result of finding that a rise of over a degree (Fahrenheit) had taken place in the thermometers located

* See Bibliography.

over the centre for the arm on the left side of the head only. This result, although rather surprising, was not wholly unlooked for.

When the experiments were resumed in the winter of 1879, the following propositions were made their basis:

First. Marked local variations in the temperature of the cephalic contents can be demonstrated by surface thermometers (Broca, Gray, Maragliano, etc.)

[The fact that thermometric fluctuations, occurring on the surface of the head, have led observers to the diagnosis of subjacent cerebral lesions known to cause temperature variations (Broca, Gray, Mills, Putnam Jacobi, etc.) seems evidence enough that the heat of the brain can be transmitted through the dura mater, skull and scalp. To these facts we have added, however, the experiments of Maragliano on the cadaver, which demonstrated that the heat from warm water in the cranial cavity was transmitted through the cerebral envelopes in sufficient amount to affect surface thermometers.]

Second.—Cerebral cortical localization is now so far advanced as to warrant the assertion that the psycho-motor centres for one half the body occupy a certain area in the cerebral cortex of the opposite hemisphere.

Third.—Functional activity of an organ implies increased blood-supply and tissue-change, and consequent elevation of the temperature of that organ.

Fourth.—Willed contraction of muscles presupposes an increased activity of the volitional motor centre of those muscles in the cerebral cortex.

From the above propositions, it was very natural to make the deduction, that voluntary activity in a peripheral part causes a rise of temperature in the psycho-motor centre for that part which may be indicated by external cerebral thermometers.

APPLIANCES FOR EXPERIMENTATION AND SELECTION OF SUBJECTS.

The thermometers used in the following experiments were the self-registering Seguin surface thermometer* (having a flattened, circular reservoir), as modified by Gray, of Brooklyn. The chief modification claimed by Gray consists in a peculiar annealing or strengthening of the glass of the bulb to prevent its susceptibility to pressure. The thermometers are 11 cm. long, have a bulb 1 cm. in diameter, have a twist in the stem, to prevent the column of mercury from being lost, and are graduated in the Fahrenheit scale (a modification of doubtful utility) from 80°–100.° In the first experiments use was made of the perforated strap first used by E. Seguin† and modified by Gray for special use on the head. This mode of appliance was found entirely inadequate, for the reason that while it secured a good general distribution of thermometers, it was impossible with it to concentrate a number of thermometers in a small and peculiarly located area. A perforated sheet of felt was tried, but found unsatisfactory, and recourse was finally had to a quadrilateral piece of sheet rubber of sufficient elasticity to fit the convexity of the head, and stiff enough to tend to keep the thermometers erect. This piece of rubber is white, 21.5 cm. long, 14 cm. wide and almost 1.5 mm. thick. It is secured in position by means of perforated straps, sewed on two corners, and straps having buckles sewed on the opposite corners. By means of this appliance (open to immense improvement) numbers of thermometers may be brought in apposition with the surface of the head, and by holes punched in the rubber, you

* E. Seguin. Human temperature and medical thermometers. New York, 1876.

† Loc. cit., p. 273: "For continuous observations a belt with numerous holes the—diameter of the stem of the instrument can maintain the latter any length of time, and experiences may go on for hours or days without preoccupation or fatigue for the patient or the observer, wherever it is of interest to follow the differences and the variations of temperature apparently caused by disease, medication, overwork, study, etc.

can scatter the thermometers or concentrate them on some particular region.

The selection of a proper subject is of great importance to the success of the experiments. In the first place he should have a normal, well-shaped head ; good frontal angle, a smooth contour of the vertex and a well developed occiput, not brachy-cephalic or dolicho-cephalic, but the mean between the two.

In the second place the hair should be thin, or if not thin, close clipped. This precaution, although not absolutely necessary adds greatly to the ease and accuracy of the experiments, the temperature variations being quicker and greater where the layer of hair is thin.

In the third place the patient should have well developed and trained muscles, and if possible, should know their actions. The power of facial expression, especially of unilateral facial movements, and the ability to contract indivinual muscles, is of great desirability.

In the fourth place, it is of the greatest importance that the subject should be possessed of moderate intelligence, and be able to keep awake when remaining at rest.

In the fifth place an European, other things being equal, will be found more satisfactory than an African subject, and a man better than a woman.

PRECAUTIONS TO BE TAKEN AND SOURCES OF ERROR.

It is of the utmost necessity to be always on the lookout for sources of error, and hence a few of the most important ones will be pointed out, and a few simple rules laid down.

1. It is always better to make observations on a subject only after he has been a certain time at complete *bodily* rest. If however, experiments are performed after muscular exertion, as walking, etc., always make a note of the form of exertion and whether violent, continued, etc., etc.

2. The temperature of the surrounding air may lead to

the grossest errors. It is in this respect particularly, that the writer objects to the use of such a delicate instrument as the thermo-electric apparatus used by Lombard, Schiff, and Hammond. The accuracy of the ordinary surface thermometer, when covered by the cotton pad and leather strap (Gray's), will be seriously affected by the heat of a study lamp held within a meter, (variations of a degree F. and more having been noticed), while by ordinary gaslight, such variable results have been obtained as to show the utter worthlessness of experiments made with artificial light, unless extraordinary precautions are taken.

Rooms where there are currents of air, warm or cold, are unsafe for accuracy. If such slight causes affect a thermometer graduated to quarters of a degree, what can we say of the dependence to be placed on the indications of a thermometer showing fluctuations of one thousandth of a degree? Perhaps Lombard, by encasing his thermo-pile in ebonite and surrounding it with cotton, and then binding it so tightly on the head as to produce a local anæmia of the scalp may arrive at accurate results, but by pressure on the scalp he does not produce anæmia of the vessels of the diploë or dura mater, and so his thermo-pile may still be affected by vascular disturbances.

Lombard's experiments it is believed, were performed with excessive care and his results are thought to be perfectly accurate, and the variations in his temperatures are due to variations of temperature in the brain transmitted through its envelopes; nevertheless the extreme delicacy of the instrument, which makes it of so much value in careful hands, opens it to the most serious objections as an instrument for general and more careless use.

The most satisfactory results are obtained in a moderately cool room, 70° F., and particularly one of an equable temperature. Temperatures taken in a hot room, 85° F. and upward are useless, the variations are so small.

3. In experiments on the two sides of the same head, care must be taken to locate the thermometers similarly on the two sides.

4. Exert, in all experiments, as nearly as possible, an equal amount of pressure on the bulb.

5. See that the subject makes only one movement, or contracts only one muscle or group of muscles at a time,* and see that all these movements are vigorous, *willed* and contract the muscles forcibly. The importance of this rule is due to the fact that passive or flimsy movements produce no effect at all in the surface temperature of the head.

THE MODE OF PERFORMING AN EXPERIMENT.

The subject is placed at ease in a chair and the thermometers, with the pad of cotton over their bulbs, are thrust through openings in the rubber sheet and arranged at equal distances from each other in such a manner as to cover as much space as possible, and the whole is applied to the head by means of the straps and buckles.

The temperatures are recorded after from ten to fifteen minutes of quiet, and then the subject is directed to make some vigorous, willed movement, contraction of the biceps for example, for from five to ten minutes, and at the end of five minutes after the movements cease the temperatures are to be again recorded and compared with those taken before the movements. If a marked rise of temperature is noticed in any one of them the other thermometers must be brought together and concentrated about this spot so as to define the area over which the rise of temperature takes place as narrowly as possible. The process will be called that of concentration and the results will be localization. There will generally be found a small area over which the rises in temperature are large and constant and from which

* Particular stress will be laid on this later.

they shade off gradually into the surrounding surface where there are no temperature changes.

One will soon learn to discard certain of the figures as he knows them to be indices of diffuse radiation of heat obliquely through the cerebral envelopes, from the active centre. Thus many rises of .25° to .50° F. may be ignored and only rises of .75° to 1.° and over recorded.

Much depends on the character of the muscular movements. If they are vigorous, and tonic and clonic spasms alternate, beautiful results are sometimes obtained and variations of 2° F. and more are seen.

THE MODE OF RECORDING EXPERIMENTS.

The mode of recording experiments is as follows: By means of Broca's stereograph or a shadow on the wall, transfer the outline of the head under study to paper. Make some copies of this and keep for recording future observations, and make a great many reduced copies (see Fig. 1) without Féré's lines, for the recording of individual experiments. Register the rises in temperature found, on the outline figure in a place which corresponds to its location on the head, designating its location by three measurements: first, the distance of the point from the median line of the head; second, the distance from this point, in the median line, to the root of the nose; third, the distance from the point where the temperature was taken, to the external auditory meatus. These three measurements being given, the point examined can be accurately located on the larger diagram of the head to be now described and of which Fig. 3 is a copy reduced one-third.

This diagram consists of a full-size profile view of the head, on which lines, a centimetre apart, are drawn having the meatus as a centre. The peripheral lines are made

FIG. 3.—DIAGRAM FOR RECORDING OBSERVATIONS; ONE-THIRD NATURAL SIZE.

very close together in order to roughly represent, in perspective, the convexity of the head as it approaches the median line, which in the same diagram is divided into centimetres numbered from the root of the nose backward.

Having now the perpendicular distance of any point on the head to the median line, it is easily and accurately registered on this chart.

In the following experiments it was thought best to confine the observations almost entirely to one subject, and also to experiment chiefly on the left side of the head for the reason that the muscles on the right side were much better developed and more manageable. Several corroborative experiments on the opposite side and in other subjects will be introduced from time to time.

EXPERIMENTS ON THE UPPER EXTREMITY.

Among the first experiments performed, were those to locate the centre for the upper extremity. In these experiments, in which movements of the whole upper extremity were made, (flexion and extension of the fingers and fore-arm and some rotation of the shoulder), a rise of temperature, varying from .25°—2.75° F., was caused over a rather large area, extending on the median line from a point 14 cm. behind the root of the nose, about 10 cm. back on the same line, and laterally about 9 cm. from the median line. At this juncture it suggested itself that, for muscles which could be separately contracted at will, individual areas could be located, by repeated experiments and careful exclusion of sources of error. From this point on, much more care was exercised in the measurements and in the recording of results and a new source of error was discovered, which will receive attention under each separate heading, viz., the difficulty of contracting but one muscle or group of muscles at a time, and the readiness with which associated and even antagonistic muscles are brought into action.

METHOD OF ANALYSIS AND SUBDIVISION OF THE CENTRE FOR THE UPPER EXTREMITY.

The large area in which there was noticed a rise of temperature following activity of the right upper extremity was sub-divided into smaller areas in the following manner. Prolonged and repeated contraction of the biceps caused a rise of temperature greatest near the median line, and about 19 cm. from the roof of the nose. This fact being ascertained, the thermometers were concentrated about this spot and an area was marked out about 3 cm. long and 5 cm. broad, near the median line of the head, extending from a point 17 cm. to a point 20 cm. behind the nose. (See

Plate.) This result was confirmed by four additional experiments and the boundary pretty clearly made out.

In supinating and flexing the forearm, the movement best adapted to bring about good contractions of the biceps, there are sources of error which must be guarded against. They are these: the supinator longus almost invariably contracts, it being a strong flexor as well as supinator of the forearm, and there is an involuntary tendency on the part of the subject to contract the flexors of the hand and fingers also. The best way to secure contraction of the biceps, is to have the patient bring his supinated wrist or forearm against some resisting surface, as under the edge of a heavy table or desk, and then make attempts to flex the forearm on the arm. Even then the supinator longus acts, but that is unavoidable.

In the experiments consisting in alternate flexion and extension of the forearm, a rise of temperature was noticed on an area including not only that just marked out for the biceps, but also in a region extending three or four centimetres farther back on the median line and of about the same width.

It was natural to presume that the rise of temperature in this region, was due to the contraction of the triceps in extension of the forearm, and several experiments on the triceps confirmed this supposition. The movements used to produce good contractions of the triceps were simple attempts at extension of the semi-flexed forearm, the movement being resisted by holding the patient's wrist or interposing some resistant object in his way. The results in these experiments were not so striking as in those on the biceps, for the simple reason that the triceps in the subject was not nearly so well developed as the biceps. The results were, however, sufficiently conclusive to define an area situated behind the biceps and covering a space

near the median line 3.5 cm. long and 6 cm. broad. (See Plate.)

The next series of experiments were performed to determine the location in which hand and wrist movements cause an elevation of temperature. The conclusion deduced from many experiments on movements of the hand and fingers was that in an area, at about the same distance from the nose, but farther from the median line than the brachial area, a constant and quite marked elevation of temperature took place after continued and vigorous flexion and extension of the hand and fingers. After carefully laying out this area on the graduated diagram, (see Fig. 3, p. 135), it was remarked that its upper or median border overlapped considerably the area already laid out for the biceps and triceps. Here arose a difficulty not before met and which presented itself from time to time all through the course of experimentation. The questions which immediately arose were: Do the centres for different muscles or groups of muscles overlap in the cerebral cortex (as some suppose they do) or is this apparent overlaping due to insufficient care in limiting the muscular movements and also to the oblique radiation of heat, already referred to, through the cerebral coverings? A series of experiments proved the two latter to be, in all probability, the factors in causing the apparent overlapping of the centres.

In hand and finger movements, especially in strong flexion, there was found in the subject a tendency to an involuntary and rather feeble contraction of the biceps muscle. When this error was corrected, by calling the subject's attention to it and by having the forearm extended, the overlapping of the two areas was much lessened.

When the thermometers were not left on quite so long after the movements had been performed, that is to say, giving time enough for the heat, at the point of its maxi-

mum intensity, to traverse the superincumbent tissues, but not allowing time for oblique radiation to take place, it was also found that the overlapping was very much diminished.

Bearing in mind these two precautions, and ignoring many doubtful and small elevations of temperature, the forearm and hand area was laid out, and now remained the more difficult task of dividing it.

The flexor group of the forearm was found to be best brought into action by flexion of the wrist and making the subject squeeze an elastic body, as a rubber bulb, in the hand. These experiments showed that the flexors of the wrist and fingers occupy the front part of the forearm area, an irregular tract about 3 cm. square, and lying alongside the biceps, about 6 cm. perpendicularly from a point on the median line 19 cm. from the nose (see Plate).

The extensors of the wrist and fingers and the interosseii occupied the posterior part of the forearm area a region about 4 cm. long and 2 cm. wide to the outer side and rather behind the triceps area.

It is of importance in experimenting on the flexors of the fingers to have the object grasped quite elastic, so as to enable the fingers to regain a semi-extended position, in order to be again flexed, without the contraction of the subject's extensor muscles. To accomplish this end, the rubber bulb of a syringe or Paquelin cautery was found very convenient.

In experiments on these parts, a curious physiological fact was brought out, viz., the necessity of the antagonistic contraction of the extensors of the wrist to secure the maximum power of the flexors of the fingers. It was demonstrated in this manner:

The common grasp of the subject's right hand, as shown by the dynamometer, was 26 kilogrammes.*

* Author's dynamometer was graduated under his own supervision by Stedwithey the engineer of the New York Hospital, and is exact.

Date of Experiment.	Movement or Muscle.	Area of the Head.											Average F.	Average C.
1879.	R. Biceps	Parietal B	92.5	91.	92.	91.	90.75	90.75	91.5	91.	91.75	91.75	91.5	
Dec. 31.	Triceps	b. sides. A	91.	91.25	91.25	91.75	90.75	91.	91.25	91.	91.75	92.	91.3	
" "	L.	R. B	[illegible]	93.5	89.	92.5	[illegible]	92.5	90.25	[illegible]	91.25	89.25	91.	
	"	Parietal A	91.5	93.25	91.	90.25	89.25	92.5	88.75	87.	92.	92.	91.	
1880.	R.	L. B	93.5	91.75	92.	91.	92.75	92.75	93.5	92.5	90.5	91.25	92.1	
Jan. 13.	Biceps.	Parietal A	93.75	92.25	92.25	92.	92.5	93.	93.5	92.75	92.75	92.25	92.6	
" 15.	R.	" B	91.25	90.5	91.	92.25	92.25	92.	92.	92.5	92.75	92.75	91.9	
	Biceps.	A	92.5	91.75	91.	92.25	93.25	[illegible]	92.	94.	93.75	93.	92.5	
" "	R.	" B	92.5	91.75	91.	92.25	93.25	92.	92.	94.	93.75	93.	92.5	
	Triceps.	A	93.	92.5	91.25	92.25	93.75	93.	92.5	94.	93.75	93.	92.9	
" 20.	R.	" B	94.75	94.5	94.25	95.	95.	94.	94.75	94.	93.75		94.1	
	Biceps.	A	95.	95.	94.25	95.	95.	94.	95.25	94.5	94.		94.4	
" 21.	R.	" B	91.	91.5	91.5	90.75	91.75	90.75	90.	90.5	91.25		91.	
	Triceps.	A	92.25	92.5	91.75	92.	92.75	91.	91.5	90.5	91.		91.5	
" 23.	R.	" B	92.	91.5	92.	92.	92.5	91.	92.	90.25	91.		91.3	
	Biceps.	A	92.	92.	92.5	93.	93.	92.	92.75	90.5	91.25		91.9	
" "	R.	" B	92.	92.	92.5	93.	93.	92.	92.75	90.5	91.25		92.2	
	Triceps.	2d A	92.75	92.75	93.	93.	93.25	92.	93.	90.5	91.5		92.4	
Feb. 19.	R.	subject. B	93.5	91.25	92.75	93.5	93.5	93.25	92.75	93.75	92.25		92.9	
	Triceps.	" A	94.	91.5	93.5	94.25	94.25	94.5	93.25	94.	92.5		93.3	
1879.	R. Biceps	Negro. B	92.25	92.25	92.60	92.75	92.75	92.25	92.60				[illegible]	
Nov. 19.	& Triceps	" A	92.25	92.25	92.75	92.85	93.	92.5	92.75				92.6	
" "	"	Negro. B	[illegible]	91.75	92.5	91.5	91.75	91.5	92.				91.8	
		2d exp't A	91.5	92.	92.5	[illegible]	92.25	92.	92.25				92.	
												Average all,	92.2	33.4
1880.	Flexors	L. B	92.75	92.	90.75	91.75	93.	93.5	92.5	93.5	93.5	92.25	92.4	
Jan. 14.	Forearm.	Parietal A	93.5	93.	93.75	93.75	93.75	93.75	93.	94.	93.75	93.75	93.5	
" 15.	Exten-	" B	[illegible]	91.75	90.75	91.75	92.75	91.	91.75	92.5	91.75	89.25	91.4	
	sion.	A	91.25	90.75	90.5	90.25	92.25	91.25	92.	92.5	91.75	91.	91.3	
" "	Flexors	" B	91.25	91.75	90.75	91.75	92.75	91.	91.75	92.5	91.75	89.25	91.4	
	fingers.	A	91.25	91.75	90.75	92.25	92.75	91.75	92.	92.5	91.75	90.75	91.6	
" "	Flexors &	" B	92.	92.5	91.75	91.5	93.	91.	91.	92.75	93.5	92.	92.1	
	Extens's.	A	92.5	93.	92.5	92.	93.25	92.	92.5	93.	93.75	92.25	92.6	
" 19.	Flexors.	" B	93.25	93.	92.5	93.25	93.	92.5	92.5	92.	93.		92.8	
		A	92.5	92.5	93.	93.	92.	92.25	93.	92.	93.		92.7	
" "	Extens's.	" B	92.5	92.5	93.	93.	92.	92.25	93.	92.	93.		92.7	
		A	91.75	93.5	93.	93.	93.	92.5	93.	92.	92.5		92.7	
" 20.	Flexors.	" B	90.25	91.5	92.	91.25	91.75	91.75	91.5	89.5	90.5		91.1	
		A	90.25	91.75	91.75	91.25	92.	91.	91.5	90.5	91.5		91.2	
" "	Extens's.	" B	90.5	92.25	92.5	91.25	92.25	91.75	92.25	90.75	91.		91.5	
		A	92.	91.5	92.25	92.	92.	90.75	[illegible]	89.75	91.		91.4	
" "	Flexors.	" B	93.5	93.5	94.	94.	94.	93.25	94.	92.5	93.25		93.3	
		A	93.5	93.5	94.	94.	94.	93.5	94.	93.	93.5		[illegible]	
" "	Extens's.	" B	93.5	93.5	94.	94.	94.	93.5	94.	93.	93.5		93.6	
		A	94.5	94.25	94.	94.	94.25	94.	94.	93.5	93.5		94.	
" 22.	"	" B	90.75	91.	91.5	91.75	91.75	91.	92.25	[illegible]	91.		91.3	
		A	91.	91.	91.5	92.	91.5	91.75	92.75	91.5	90.5		91.5	
1879.	Flexors &	R. B	92.	91.5	91.	92.	93.5	92.5	93.25	93.5			92.1	
Nov. 23.	Extens's.	Parietal A	92.	92.	91.5	92.	93.5	93.	93.5	93.5			92.3	
	Negro.													
												Average all,	92.1	33.4

His hand was held in a semi-extended position, that being the one, as anyone can see for himself, in which the maximum grasping power is obtained. Causing him now to flex the hand and then grasp the dynamometer, a power of only 5 kilogrammes was exercised, a reduction of over four-fifths.

This fact is simply introduced as exemplifying one of the sources of error (see p. 131) to be guarded against. It is

not the proper place here to try and explain the cause of this variation. The existence, however, of this physiological antagonism tends to explain a certain overlapping of the flexor and extensor areas which would otherwise be confusing. There are many indications, but no positive proofs, that the area for the supinator longus lies between the flexor and the biceps, as the similarity of their action would favor the presumption of their proximity. Subjoined (p. 140) is a table of the temperatures taken in experiments on the upper extremity.

A DEMONSTRATION OF THE MODE OF SUBDIVISION OF A LARGE AREA INTO INDIVIDUAL AREAS.

Having gone in considerable detail over the mode of experimenting and the results of the experiments on the upper extremities, it is thought best to give a demonstration, by means of a diagram (see Fig. 4), of the mode of subdividing an area, corresponding to large groups of muscles, and, by means of the recorded results, the authority of drawing sharp lines of demarkation between separate areas.

The mode of procedure is as follows:

Rule a paper into square centimetres. Call one of these lines the median line of the head, and on it place numbers showing the distance, in centimetres, from the nose. Now take the diagrams (see Fig. 3) on which have been recorded the rises of temperature occurring in all experiments, and transfer them to the ruled diagram, placing alongside each elevation the initial of the muscle or group of muscles (*b* for biceps, *f* for flexors) whose contraction caused it.

After all temperatures have been transferred, a glance over the page will betray a more than accidental division of the region into several different areas in which there will be

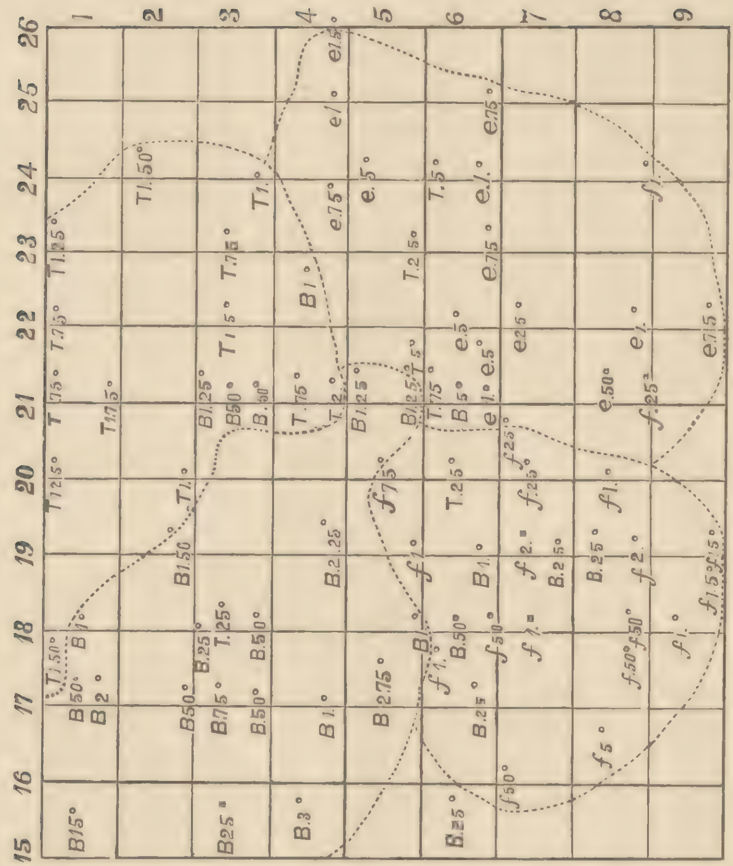

FIG. 4.—A diagram showing the elevation of temperature found in the experiments on the upper extremity, and also the mode of subdividing a large into smaller areas.

seen foci of high temperatures, evidently the areas which overlie individual centres. These foci will generally be found to shade off into each other by a gradual diminution in the magnitude of the rise, and a point is generally found which appears to be neutral ground, so to speak, and it is through this ground that a line of demarkation must be drawn.

These lines are not always easy to draw, however, and as an instance of this fact may be given the boundary line be-

tween the biceps and triceps. At a point, about 3 cm. perpendicularly distant from the point 21 cm. of the median line, is seen a group of temperatures which read as follows: B, 1.25°, .5°, .5°, (which means that elevations of those amounts of Fahrenheit took place there subsequent to contractions of the biceps), and T, .75° and 2°. Although the biceps figures largely in this region, it is thought best to enclose it within the tricep's boundary for the reason that a a rise of 2° F. after the exercise of a weak muscle like the triceps, in the subject, indicates more than a rise of 1.25° F. after activity of a strong muscle like the biceps. The occurrence of such embarrassments is fortunately not common, and generally the line of demarkation can be easily drawn.

EXPERIMENTS WITH SHOULDER MUSCLES.

In the experiments performed on the upper extremity as a whole, including some shoulder movements, elevations of temperature were noticed over a greater surface than the area that has just been laid out as belonging to the arm, forearm and hand.

The posterior boundary was the same in both, but in the former series of experiments there was noticed a rise of temperature in front of the biceps area. It occurred to the writer that here might be located areas for the shoulder muscles, and so experiments were performed which fully confirmed this supposition.

The complexity of movements inherent in a ball-and-socket joint, like the shoulder, abduction, adduction and circumduction of the arm, elevation, depression, propulsion and retraction of the scapula plunged the experimenter into such a maze that a clear, definite result was almost dispaired of. Frequent repetition of experiments, and careful sifting of results, however, at length brought comparative order out of the seeming chaos.

General movements of the shoulder joint and scapula were found to cause an elevation of temperature over a very large surface, being anterior to the area for the arm, approaching very nearly the supra-orbital ridge in front, and extending laterally over a region 8 or 9 cm. broad.

The deltoid, it being nearer the arm muscles aleady located, was first selected for experiment. It was brought into action by abducting the extended arm and hand sometimes with and sometimes without a light weight in the hand, or hung on the forearm. The subject must be watched lest, in this experiment he contract some arm or forearm muscle. The rises of temperature after this movement commenced at the biceps area, and extended some distance forward next the median line. It was now noticed that this movement, intended to contract the deltoid alone, brought into action the upper part of the trapezius and the levator anguli scapulæ which two muscles fixed the scapula, when the deltoid, taking this as its fixed point, contracted and raised the arm.

To mark out the area for the deltoid, it would then be necessary to strike off from the larger area the part on which rises of temperature occurred from contraction of the upper part of the trapezius and the levator anguli scapulæ.

Simple elevation of the scapula, shrugging the shoulder, which brought these latter muscles into action, produced a rise of temperature in the anterior part of this region leaving a space 5 cm. long and 4.–5 cm. broad as the deltoid area, extending from the biceps area forward on the median line to within 13 cm. of the nose. This area was narrower in front than behind, the highest temperatures being found near the median line of the head.

In determining the area for the deltoid, the location of the area for the upper part of the trapezius and levator

anguli scapulæ were pretty well defined, but numerous experiments were superadded to insure certainty. The movement used was simple elevation of the shoulder (as in shrugging), the arm hanging limp.

More marked results were obtained by resisting the movement by putting the subject under some fixed object, as a mantle shelf, and making him attempt lifting the same. The head must be held still in these experiments to offer a fixed point for the muscles involved.

Rises of temperature followed over a rather large space extending along the median line from the anterior margin of the area for the deltoid, to within 5 or 6 cm. of the nose, and being 6 to 6.5 cm. broad.

In experiments on the pectoralis major, the arm being adducted, carried across the chest, and the shoulder depressed, rises of temperature were seen in an area situated between those already marked out for the trapezius and deltoid external to both. This area was about 3 cm. long and 3–4 cm. wide opposite a point on the median line, 14 cm. from the nose. There was found to be considerable overlapping of the areas for the deltoid and pectoralis, which is accounted for probably by the fact that the anterior fibres of the deltoid enter quite largely into the above movement.

In depression of the scapula, calling into action the muscles used in supporting the body on crutches, there was an elevation of temperature over a large area, partly allotted already to the trapezius and pectoralis major. In having the subject depress and slightly retract the shoulder, so as to prevent the action of the pectoralis major, the most marked elevation of temperature took place in an area immediately behind that for the pectoralis major, and of about equal size. This was allotted to the latissimus dorsi, that being the muscle most involved in this movement.

The elevations of temperature occurring in depression of the shoulder over the area for the trapezius, is explained by the part the lower fibres of this muscle play in this movement. The distribution of these rises, however, did not coincide exactly with the area already laid out for the upper part of the trapezius, but extended more laterally.

Horizotal retraction of the shoulder, and contraction of the middle part of the trapezius and the rhomboids, caused a rise of temperature in an area overlapping that for the upper part of the trapezius, but extending farther forward in the median line.

There is thus marked out a large area, 9 cm. long and 4.–7 cm. broad, which may be called the trapezius area, although lost in this tract somewhere are probably the areas for the levator anguli scapulæ and the rhomboids. It will be noticed that this area comes forward to within 3 cm. of the nose. An area for the serratus magnus could not be located because the muscle cannot be contracted singly. Judging, however, from its action, pulling the scapula forward, and drawing the lower angle forward, tending to raise the apex of the shoulder, it would seem likely to occupy an area near that of the trapezius and pectoralis major, and perhaps it is located partially on the space already assigned to them. (See Table on p. 147.)

Experiments on movements of the head and neck early occupied the writer's attention. The extreme complexity of the movements and the multitude of muscles involved in them, were for a long time the source of great bewilderment, but a careful analysis of the movements and muscles involved soon afforded a partial solution. So much difficulty was experienced in disentangling the facts deduced from these experiments, that a brief analysis of them will perhaps be pardoned.

Movements of the head alone must be kept distinct from

Date of Experim'nt	Movement or Muscle	Area of Head												Average F.	Average C.
1879.	Shoulder	Later'l	B	93.5	93.	93.	91.75	92.75	92.75	93.25	93.	92.	92.25	92.75	
Jan. 13.		frontal	A	[illegible]	93.	93.	92.5	92.75	93.	93.25	93.	92.5	92.5	92.9	
" 15.	"	"	B	91.	91.75	92.	91.75	92.5	91.5	92.	90.75	92.	92.	91.77	
1880.			A	91.25	91.75	[illegible]	91.75	93.	92.	92.	91.5	92.	92.5	91.97	
Jan. 16.	Elevators	"	B	89.	89.5	89.	90.	91.5	91.	91.5	88.5	90.25	90.5	90.2	
	of S.		A	[illegible]	[illegible]	89.	90.25	91.5	91.	91.5	89.5	90.25	90.5	90.4	
" "	Pectoralis	"	B	89.75	89.5	89.	90.25	91.5	91.	91.5	89.5	90.25	90.5	90.4	
	Major		A	91.	92.	91.	91.5	91.75	91.	91.5	91.75	90.25	90.5	91.4	
" "	Retract'n	"	B	91.	92.	91.	91.5	91.75	91.	91.5	91.75	90.25	90.5	91.4	
			A	91.	92.	91.	91.5	92.5	92.25	91.5	91.75	90.25	90.5	91.4	
" "	Adduct'rs	"	B	91.	92.	91.	91.5	92.5	92.25	91.5	91.75	90.25	90.5	91.4	
			A	91.	92.	91.	91.75	92.5	92.25	91.5	91.75	90.25	90.75	91.4	
Jan. 22.	Deltoid	"	B	91.25	91.5	90.75	90.5	90.75	89.25	90.25	90.	89.25		90.3	
			A	90.5	92.	90.25	90.5	90.5	[illegible]	90.5	89.5	91.25		90.5	
" "	Elev'rs of	"	B	90.75	92.	90.75	90.	90.25	89.5	89.5	89.25	89.25		90.1	
	Shoulder		A	91.25	91.5	90.75	90.5	90.75	89.25	90.25	90.	89.25		90.5	
" "	Pectoralis	"	B	91.25	91.5	90.75	90.5	90.75	89.25	90.25	90.	89.25		90.5	
	Major		A	90.75	91.75	91.5	90.5	91.25	89.25	88.75	90.	90.5		90.5	
Jan. 23.	Deltoid	"	B	91.	92.	91.5	91.	92.25	91.75	91.5	92.5	93.75		91.9	
			A	92.	92.	92.	91.5	92.5	92.	91.75	92.5	93.75		92.2	
" "	"	"	B	92.75	92.75	93.	93.	93.25	92.	93.	90.5	91.5		92.4	
			A	93.	93.	93.	93.5	93.5	92.	93.5	91.	92.		92.8	
" "	Elevation	"	B	90.5	91.25	91.	90.5	91.75	91.	90.5	91.5	93.		91.2	
	Shoulder		A	91.	92.	91.5	91.	92.25	91.75	91.5	92.5	93.75		91.9	
" "	Pectoralis	"	B	92.	92.	92.	91.5	92.5	92.	91.75	92.5	93.75		92.2	
	Major		A	92.25	92.5	92.25	91.5	93.	92.5	92.25	[illegible]	94.		92.5	
" 24.	Deltoid	"	B	90.75	92.	91.5	91.	90.	89.5	90.25	89.75	90.5		90.5	
			A	91.25	92.5	92.	91.75	90.75	90.	91.5	90.5	90.5		91.	
" "	Elevation	"	B	91.5	92.	92.	92.	93.5	91.	92.	92.5	93.5		92.2	
	Shoulder		A	92.25	92.5	92.5	92.25	94.25	91.5	93.	93.25	93.5		92.8	
" "	"	"	B	91.25	92.5	92.	91.75	90.75	90.	91.5	90.5	90.5		91.	
			A	91.25	92.5	92.	91.75	90.75	90.	91.5	90.5	90.5		91.	
" 25.	"	"	B	89.	90.	89.5	89.25	91.	89.	90.	91.5	92.		90.1	
			A	89.25	91.	90.75	91.	92.25	90.5	90.75	92.5	93.		91.1	
" 27.	Pectoralis	"	B	91.5	92.	92.25	91.5	89.75	91.5	92.	93.	93.5		91.9	
	Major		A	92.25	93.	92.5	92.25	89.75	92.5	92.75	93.25	94.25		92.5	
" "	Depress'n	"	B	92.	92.5	92.5	92.	92.	91.25	92.5	92.75	91.5		92.1	
	Shoulder		A	92.	92.75	92.75	92.5	92.	91.25	92.75	93.	91.75		92.3	
" "	Retract'n	"	B	91.5	92.	91.5	91.5	91.75	90.75	92.	92.5	91.		91.6	
	Shoulder		A	92.	92.5	92.5	92.	92.	91.25	92.5	92.75	91.5		92.1	
" 30.	Pectoralis	"	B	90.25	90.5	89.	91.	89.	88.	91.	91.5	89.5		89.9	
	Major		A	92.	91.25	90.	90.75	88.5	89.75	91.25	92.25	90.75		90.7	
" 31.	Elevation	"	B	92.	92.75	93.	92.5	93.5	90.	93.25	93.5	94.5		92.7	
	Shoulder		A	92.5	93.	93.25	92.5	93.75	91.25	93.5	94.	94.75		93.1	
" "	Retract'n	"	B	92.5	93.	93.25	92.5	93.75	91.25	93.5	94.	94.75		93.1	
	Shoulder		A	92.5	93.25	93.25	93.	94.	91.75	93.75	94.	94.75		93.3	
" "	"	"	B	91.25	92.	92.25	91.5	93.	89.25	93.	93.25	94.25		92.1	
			A	92.	92.75	93.	92.5	93.5	90.	93.25	93.5	94.5		92.7	
Feb. 2.	Pectoralis	"	B	91.75	91.5	90.5	91.	92.	89.5	90.	90.	91.5		90.8	
	Major		A	92.	91.75	90.75	91.	92.	90.	90.	89.75	91.5		90.9	
" "	Depress'n	"	B	90.5	90.5	89.5	91.	91.5	89.5	89.	89.	91.		90.	
	Shoulder		A	91.75	91.5	90.5	91.	92.	89.5	90.	90.	91.5		90.6	
" 4.	Elevation	"	B	91.5	91.25	92.75	93.5	93.25	93.	93.5	94.75	93.		92.9	
	Shoulder		A	91.5	91.25	92.75	93.5	93.5	93.	93.5	94.75	93.25		93.	
" 7.	Pectoralis	"	B	93.	94.	92.5	92.5	92.75	93.5	91.	92.5	91.5		92.5	
	Major		A	93.5	94.25	93.5	93.25	93.25	93.5	92.	93.	92.25		93.1	
" "	Depress'n	"	B	93.5	94.25	93.5	93.25	93.25	93.5	92.	93.5	92.25		93.1	
	Shoulder		A	93.75	94.25	93.75	93.25	93.5	93.5	92.	93.5	92.25		93.1	
" 11.	"	"	B	92.75	93.25	93.25	92.	92.	94.	92.25	92.5	93.25		92.7	
			A	93.75	94.25	94.25	93.	93.	94.5	93.	93.25	94.		93.6	
													Average,	91.9	33.3

movements of the head and neck. The movements of the head alone are confined to nodding, and those of the head and atlas to rotation.

The head is pulled forward by the recti capitis antici

and the hyoid group of muscles, backward by the trapezius, complexus, splenius capitis and other powerful muscles at the back of the neck, while rotation of the head is caused by the oblique and unilateral action of the muscles which pull the head forward and backward.

Movements of the head and neck as a whole, however, bring into action more muscles. The head and neck are bent forward, not only by the muscles already named as bending the head, but also by the sterno-mastoids, scaleni and longus colli. Lateral movements of the head and neck are caused by the trapezius, levator anguli scapulæ, etc., while extension of the head and neck, as of the head alone, is caused chiefly by the trapezius, complexus, splenius, etc., etc.

In general movements of head and neck, nodding, rotary and lateral, temperature changes were noticed over a considerable area in the lateral frontal region more remote from the median line than the shoulder region already mapped out.

Forced extension of the head and neck, sometimes directly back, at other times toward the right side, produced elevations of temperature in two places: first in the anterior frontal region assigned to the trapezius and levator anguli scapulæ, and second in the lateral frontal region over a small area, external to that of the pectoralis major, opposite a point on the median line, about 14.5 cm. from the nose. This area is about 3 cm. long and 1.5–2 cm. wide. In or near this area are noticed also the elevations of temperature occurring in rotary movements of the head, so this spot is designated as the area for the deep extensors and rotators of the head, the action of the superficial muscles (trapezius, etc.) having its index in the rise of temperature which occurs over the trapezius area.

Ante-flexion of the head and neck so as to bring the chin

forcibly against the chest, or better still, if the forehead be firmly pressed against some resistant body, caused a marked but rather diffuse rise of temperature in this latero-frontal region. After a great many experiments there were found to be in this area, three foci where the rises of temperature were always most marked,—one 8–9 cm. laterally from a point on the median line 16 cm. from the nose, another the same distance from the median line, 10 cm. from the nose, and the third about 10 cm. perpendicularly from a point on the median line 13 cm. from the nose. The latter district was about 8 cm. above and in front of the meatus auditorius externus.

There were also elevations, sometimes quite large, over the area where the pectoralis major had been located. How were these conflicting results to be harmonized? It was accidentally discovered that in forcible ante-flexion of the head and neck there was contraction of the pectoralis major, this taking place in order to steady the shoulder and fix the clavicle, upon which some traction was made by the sterno-cleido-mastoid.

This occurrence being pretty constant the rises of temperature found over the area for the pectoralis major were ignored. But how apportion the other three regions?

In this movement three sets of muscles are involved, viz., the hyoid group, the deep cervical group (longus colli, recti and scaleni) and the sterno-mastoids. In simple flexion of the head on the neck the sterno-mastoids are not used. Several experiments on this movement alone showed marked rises in the two higher, only, of the foci mentioned above. This would point to the lower as the region for the sterno-mastoid, and this was confirmed by several experiments on the sterno-mastoid alone, the head being rotated to the opposite side and the chin slightly elevated. The results confirmed the supposition that the lower of these

three areas belonged to the sterno-cleido-mastoid muscle. The elevations of temperature following movements of the tongue, to be described later, were found to occupy about the same location as the posterior of the two upper areas.

The same statement holds good as to the results of experiments on the depressors of the lower jaw, and for these two reasons this area was allotted to the hyoid group of muscles.

This arrangement would leave the anterior and larger region as the location of the area for the deep, anterior cervical muscles. This view is strengthened by the fact that this group contains the scaleni which would be quite

Date.	Movement or Muscle.	Region of the Head.												Average F.	Average C.
1880.	Head and	Lateral	B	92.	92.	91.5	92.	91.75	90.5	93.25	92.	89.75		91.6	
Jan. 29.	neck	frontal.	A	93.	92.	91.75	92.5	91.5	92.	93.25	93.75	91.		92.3	
" 31.	forward.	"	B	92.5	91.25	92.5	92.	90.5	91.25	92.	92.	91.		91.6	
			A	93.	92.25	93.5	92.25	90.5	92.	92.5	93.	91.		92.2	
" 16.	"	"	B	92.	90.25	91.	90.5	92.25	92.25	91.5	92.	92.75	92.25	91.4	
			A	92.	90.25	91.	91.5	92.25	92.25	92.25	92.	93.25	92.25	91.9	
" "	Head	"	B	92.	90.25	91.	91.5	92.25	92.25	92.25	92.	93.25	92.25	91.9	
	to right		A	92.	90.25	91.	91.75	92.25	92.25	92.25	92.25	93.25	92.25	91.9	
" "	side.	"	B	92.	90.25	91.	91.75	92.25	92.25	92.25	92.25	93.25	92.25	91.9	
			A	92.	91.75	91.	92.5	92.25	92.25	92.25	92.25	93.25	92.25	92.1	
" "	Back & to	"	B	92.	91.75	91.	92.5	92.25	92.25	92.25	92.25	93.25	92.25	92.1	
	right side.		A	92.	92.5	92.25	94.5	92.25	92.25	92.25	92.25	93.25	94.25	92.7	
" "	Rotation	"	B	92.	92.5	92.25	94.5	92.25	92.25	92.25	92.25	93.25	94.25	92.7	
	to right.		A	92.	92.5	92.25	94.5	92.25	92.25	92.25	92.25	93.25	94.25	92.7	
" "	Rotation	"	B	92.	92.5	92.25	94.5	92.25	92.25	92.25	92.25	93.25	94.25	92.7	
	to left.		A	92.	92.5	92.5	94.5	92.5	92.25	92.5	92.25	93.25	94.25	92.7	
Feb. 4.	Head and	"	B	92.	92.5	93.75	93.75	91.	91.5	92.75	94.	93.75		92.9	
	neck		A	92.5	93.5	94.25	94.75	92.	92.5	93.75	94.	94.5		93.5	
" 5.	forward.	"	B	92.75	93.25	93.	92.	93.	92.75	91.5	93.	92.		92.5	
			A	93.	93.5	93.	92.	93.	93.	91.5	93.	92.		92.6	
" 14.	"	"	B	94.5	94.5	94.25	94.	94.5	95.	94.	94.	95.		94.4	
			A	94.75	94.5	94.5	94.	94.5	95.25	94.25	94.25	95.5		94.6	
" 17.	"	"	B	94.25	93.75	93.	93.75	93.	92.5	93.	93.	93.		93.2	
			A	94.25	93.75	93.75	93.75	93.	93.	93.25	93.25	93.25		93.4	
" 5.	Sterno-	"	B	91.	92.5	92.	91.	92.25	92.	90.75	92.5	91.5		91.7	
	mastoids.		A	92.75	93.25	93.	92.	93.	92.75	91.75	93.	92.		92.6	
" 14.	"	"	B	94.	94.	93.75	93.5	94.	94.	93.5	93.5	94.25		93.8	
			A	94.5	94.5	94.25	94.	94.5	95.	94.	94.	94.75		94.4	
" 19.	"	"	B	93.75	94.5	94.	94.25	95.	94.5	94.25	94.75	95.5		94.5	
			A	93.75	94.75	94.	94.5	95.25	95.	95.	95.25	95.75		94.8	
Jan. 29.	Head to	"	B	92.5	92.75	90.75	92.75	91.25	92.	92.5	93.	92.		92.1	
	right side.		A	92.5	92.5	92.	92.75	91.	91.	93.25	93.5	90.75		92.1	
" 14.	"	"	B	91.75	89.75	90.25	92.5	92.5	90.75	89.25	93.	91.75	92.	91.3	
			A	91.75	88.75	91.5	92.5	92.5	91.5	91.25	93.	92.	92.	91.6	
" "	Head	"	B	91.5	91.25	91.25	91.	92.	90.75	90.25	91.5	90.5	90.75	91.0	
	backw'd.		A	91.5	91.	91.25	92.	92.	90.75	90.5	91.5	90.5	91.	91.2	
" 31.	"	"	B	93.	92.25	93.5	92.25	90.5	92.	92.5	93.	91.		92.2	
			A	93.5	91.	93.5	92.75	91.5	92.	92.75	93.	91.		92.3	
Feb. 18.	"	"	B	93.	94.	93.75	94.5	95.	94.	94.75	94.5	95.		94.2	
			A	93.5	94.5	94.	94.5	95.	94.25	94.75	94.5	95.		94.2	
													Average,	92.6	33.7

naturally sought near the other muscles of forced inspiration, viz., the elevators of the shoulder and the pectoralis major.

EXPERIMENTS ON THE LOWER EXTREMITY.

Judging from the order in which the areas for the upper extremity were developed, the posterior part of the head was naturally looked to as the place where elevations of temperature would be found following activity of the lower extremity.

It was found that general movements of the leg and thigh caused an elevation of temperature over an area of indefinite extent lying behind that of the upper extremity.

The movement of flexing the foot on the leg and extending the toes, *i.e.*, contraction of the anterior tibial and part of the peroneal group of muscles caused an elevation of temperature in an area 4 cm. long and about 5 cm. wide, lying next the median line immediately behind the area for the triceps. This area also abutted against and overlapped the area for the extensors of the forearm. (See plate.)

The movement best adapted for this experiment, the subject sitting in a chair, was found to be a simple forcible elevation of the foot and toes—the heel remaining on the floor.

Extension of the foot on the leg and flexion of the toes, *i.e.*, contraction of the calf muscles, caused a rise of temperature over an area, behind the anterior tibial, 2.5 cm. long on the median line, 5 cm. broad and sending a prolongation 1 cm. broad outside of the anterior tibial region as far forward as the area for the extensors of the forearm. The movement made was simple extension of the foot on the leg, the toe remaining on the floor. Better results were obtained when a weight was placed on the knee. The rises marked in some of these experiments were quite

Date.	Movement or Muscle.	Area of Head.												Average F.	Average C.
1880.	R. Leg.	L. Post.	B	91.	91.5	90.	85.5	89.5	90.5	90.5	89.	91.5	91.75	90.	
Jan. 1.		Parietal	A	91.25	92.	90.75	85.5	89.5	91.	90.75	88.75	90.25	92.5	90.2	
" "	L. Leg.	R. "	B	89.5	89.	89.25	89.75	89.75	88.	89.5	88.5	90.	88.75	89.2	
			A	89.5	88.5	89.	89.75	89.75	88.5	89.5	90.25	90.5	90.	89.4	
" 13.	R. Ant.	L. "	B	93.5	92.	92.25	91.5	92.75	93.	92.5	92.	91.75	92.5	92.3	
	Tibials.		A	93.	93.5	92.75	91.25	92.	92.75	93.25	93.25	92.25	91.5	92.3	
" 17.	"	"	B	91.25	93.25	91.5	92.	90.5	90.75	91.5	90.5	90.25		91.2	
			A	91.25	93.25	92.25	92.	92.	91.5	91.75	91.5	90.25		91.7	
" "	R. Calf.	"	B	91.25	93.25	92.25	92.	92.	91.5	91.75	91.5	90.25			
			A	91.25	93.25	92.25	92.	92.	91.5	91.75	91.5	91.25		92.	
" 19.	"	"	B	92.75	94.	93.5	94.5	94.25	93.	94.5	94.	93.		93.7	
			A	93.5	94.75	93.75	94.75	94.75	93.5	94.75	94.25	94.25		94.2	
" "	R. Ant.	"	B	93.5	94.75	93.75	94.75	94.75	93.5	94.75	94.25	94.25			
	Tibials.		A	93.75	94.75	93.75	95.25	94.75	93.75	95.	94.5	94.5		94.5	
" 20.	R. Calf.	"	B	90.75	92.25	92.25	92.	92.75	90.75	91.75	91.5	91.75		91.7	
			A	91.5	93.	93.	91.75	93.	91.75	92.	91.	91.		92.	
" "	"	"	B	90.	92.	92.	91.5	92.25	90.25	91.5	90.5	90.5		91.1	
			A	91.	92.	92.	91.5	92.5	89.75	91.5	90.5	91.		91.3	
" "	"	"	B	91.	92.	92.	91.5	92.5	89.75	91.5	90.5	91.			
			A	91.	92.5	92.	92.5	92.5	91.5	91.75	91.	90.75		91.7	
" 24.	"	"	B	91.25	91.5	91.	91.25	91.	90.	91.75	90.5	90.		90.9	
			A	91.25	92.	92.25	92.	92.	90.75	92.75	91.5	91.5		91.5	
" 29.	"	"	B	93.5	93.5	93.75	91.75	92.	90.75	92.75	92.5	91.		92.5	
			A	92.25	93.	93.75	93.25	92.75	91.	92.5	92.75	91.5		92.	
" "	R. Ant.	"	B	92.25	93.	92.25	92.25	93.25	92.	92.5	91.25	91.		92.1	
	Tibials.		A	92.25	93.	92.75	92.25	93.25	92.	92.5	91.25	91.5		92.3	
" 31.	"	"	B	91.	93.	92.75	92.	92.75	90.75	91.75	91.25	91.75		91.9	
		Negro.	A	92.5	93.	92.75	92.	92.75	90.75	92.	91.5	91.75		92.1	
1879.	"	"	B	95.	95.25	94.5	95.25	94.75	95.	95.75	94.5	94.75	95.	94.9	
Nov. 28.		Negro.	A	95.	95.25	94.5	95.25	94.75	95.	96.	95.	96.	95.	95.	
" "	L. Calf.	R. "	B	95.25	96.	94.75	96.	95.	95.25	95.25	94.5	95.25	94.75	95.1	
			A	95.25	96.	95.	95.75	95.5	95.25	95.75	94.75	95.75	95.5	95.4	
Dec. 1.	L.	R. "	B	90.5	90.75	90.5	89.75	90.	89.5	89.5	91.			90.1	
	Tibials.		A	91.	91.25	91.25	90.5	91.	89.75	90.5	91.75			90.3	
													Average,	92.1	33.4

large, the muscles of the calf being exceedingly well developed. (See Table on this page.)

Thus far the thigh muscles had not been brought into use, and although encroaching materially on that part of the head thought to cover sensory or non-excitable regions of the brain only, series of experiments on extension of the leg on the thigh (contraction of the quadriceps extensor femoris) developed the rather startling fact that activity of this large muscle caused a rise of temperature over a correspondingly large area of the posterior part of the head.

A careful compilation of eight experiments resulted in the laying out of an area occuying a position next the median line of the head, extending from the posterior boundary for the area of the calf 30 cm. behind the nose, very nearly to the occipital protuberance, 38 cm. behind the nose.

This area was on the average about 5 cm. broad, being wider at its anterior than its posterior extremity. Some rises in this area amount to as much as 2.75° F. The larger rises aggregated in the anterior extremity of the area, but rises of temperature worthy of note are seen as far back as the occipital protuberance.

Owing to the occurrence of many unsuccessful and misleading experiments, the search for a location of the flexors of the leg on the thigh was for a long time very unproductive. A careful compilation of nine experiments on this group of muscles warranted the setting aside of a pretty large area, external to the calf and in front of the quadriceps, of irregular shape, but about 5 cm. broad in both diameters. Some large elevations of temperature occurred here, the thigh flexors being large and strong muscles. The muscles are best brought out by attempting to flex the leg, the foot being fixed to the floor, the leg at right angles to the thigh. (See Table on p. 154.)

There are two sources of error in this experiment. There are almost always involuntary contractions of the leg muscles, either anterior tibials or calf, and always, it may be said, a marked antagonistic contraction of the psoas and iliacus muscles to be now described.

In flexing the thigh on the abdomen, contraction of the psoas and iliacus muscles, constant elevations of temperature are noticed over a small area, 3–4 cm. wide, lying in front of the quadriceps area, and abutting against the flexor area with the anterior extremity. Here it is that rises of temperature are often noticed in experiments on the flexors of the leg on the thigh, and which must be discarded.

It was thought that voluntary contraction of the muscles of the abdominal walls, so powerful in all expulsive efforts, might be in this region. The results of seven experiments with violent and prolonged retraction of the abdominal

Date.	Movement or Muscle.	Area of Head.												Average F.	Average C.
1880.	R. Quad.	L. Oc-	B	89.75	91.25	90.75	91.5	91.75	90.75	92.	91.	90.5		91.	
Jan. 22.	extensor.	cipital.	A	91.	91.75	91.5	92.	92.25	89.	91.25	90.5	89.75		91.	
" 24.	"	"	B	92.25	93.	92.	92.5	93.	91.5	93.5	93.	91.		92.4	
			A	92.	92.25	92.	92.25	92.25	91.25	92.5	91.	90.5		92.	
" 27.	"	"	B	91.5	90.5	91.5	91.25	90.5	91.5	92.	93.5	93.		91.7	
			A	93.25	92.	92.5	92.75	91.5	91.5	92.	93.5	93.		92.4	
" 30.	"	"	B	92.5	92.	92.	91.5	90.5	91.5	91.75	91.75	91.75		91.6	
			A	91.5	91.75	92.	91.75	91.5	91.5	91.75	91.75	90.75		91.6	
" 31.	"	"	B	91.25	93.25	92.25	92.	92.25	91.75	92.5	92.25	93.5		92.4	
			A	93.75	92.75	91.75	93.25	92.25	90.	92.	91.5	92.25		92.1	
Feb. 2.	"	"	B	91.5	92.25	91.	91.5	91.5	90.25	91.75	90.5	91.		91.2	
			A	91.	92.25	91.5	91.25	92.5	91.	92.	91.	92.75		91.7	
" 5.	"	"	B	91.75	92.75	92.75	92.25	92.5	94.	92.5	92.	93.25		92.6	
		2d subj.	A	93.25	93.75	93.25	92.75	93.	93.75	93.	93.	94.5		93.3	
" 9.	"	"	B	91.	92.	92.5	92.25	92.5	92.25	92.25	92.25	93.	93.	92.3	
			A	91.75	92.5	92.75	92.5	92.75	92.25	92.5	92.25	93.25	93.25	92.5	
Jan. 27.	Flexors	"	B	92.25	93.5	92.75	93.	91.75	91.	91.75	90.5	90.75		91.9	
	leg on		A	92.5	93.	93.	93.	92.25	92.5	93.	93.	91.75		92.5	
" "	thigh.	"	B	93.25	93.5	93.5	93.	92.25	92.75	93.25	93.75	92.5		91.9	
			A	92.	92.	91.75	92.5	90.5	94.	93.	92.75	92.75		91.7	
" "	"	"	B	93.5	93.	92.75	91.75	92.	92.25	93.	93.	91.75		92.5	
			A	92.	92.	92.	91.5	91.75	91.5	92.	92.75	91.75		92.	
" 28.	"	"	B	93.	94.	93.75	93.	92.25	93.	92.75	93.	92.		92.9	
			A	94.	93.5	94.	93.	92.	92.75	93.75	94.	92.5		93.2	
" 29.	"	"	B	92.5	92.75	92.25	92.75	92.5	92.	92.75	93.	92.		92.5	
			A	93.	92.5	92.25	92.	92.	92.	92.	91.5	91.		92.	
Feb. 1.	"	"	B	92.5	93.5	92.	92.	92.75	93.	92.25	88.75	92.75		92.1	
			A	91.	94.	92.75	92.	92.5	93.	92.75	91.25	93.5		92.6	
" 7.	"	"	B	94.	94.5	93.75	94.	94.	94.25	93.25	93.75	93.		93.8	
			A	93.25	92.75	93.5	93.	93.	93.	93.25	93.5	91.5		93.	
" 17.	"	"	B	94.25	94.5	94.5	93.25	93.5	93.25	93.25	92.75	93.		93.4	
			A	95.	94.5	94.25	94.	94.	95.	94.	93.75	93.75		94.1	
" 19.	"	"	B	93.	93.75	92.75	89.75	93.5	90.25	92.5	91.25	92.75		92.	
			A	92.	93.	93.	93.	93.	93.25	93.25	91.25	92.		92.6	
Jan. 31.	Psoas and	Lateral	B	92.25	92.75	91.75	92.75	92.25	90.	92.	91.5	92.25		91.9	
	iliacus.	occipit.	A	93.75	92.75	92.25	93.25	92.25	92.	92.25	92.	93.25		92.6	
Feb. 7.	"	"	B	92.5	91.	95.	94.25	94.	94.75	93.25	94.	94.		93.6	
			A	92.	93.	93.	93.	93.5	94.	92.	94.	93.5		93.1	
" 12.	"	"	B	92.	92.25	92.25	92.5	92.75	88.5	93.	91.5	92.75		91.9	
			A	92.5	3.	3.	3.	3.	90.25	92.	91.	92.75		92.5	
" 14.	"	"	B	95.	94.25	94.75	94.	93.75	94.75	94.25	93.5	93.25		94.1	
			A	94.75	95.	94.75	94.25	92.25	93.5	94.25	93.	93.5		94.1	
" 1.	Erector	"	B	93.75	93.	92.25	92.25	92.75	91.5	92.75	92.	93.25		92.6	
	spinae.		A	93 75	94.	93.25	93.	93.5	89.75	94.25	93.	92.5		93.1	
" "	"	"	B	93.75	94.	93.25	93.	93.5	89.75	94.25	93.	92.5			
			A	93.75	94.	93.5	93.5	94.	91.	94.25	93.25	93.25		93.4	
" 7.	"	"	B	93.25	93.25	94.25	93.25	93.25	93.	92.75	93.5	93.		93.2	
			A	95.	95.25	94.75	93.25	94.5	95.25	94.25	94.25	93.5		94.4	
" 10.	"	"	B	93.5	92.	92.	92.	92.25	92.75	93.	92.75	92.25		92.6	
			A	92.75	92.5	92.5	92.25	92.	92.5	93.	91.75	91.5		92.3	
" 17.	"	"	B	95.	94.75	95.	94.	93.	94.5	93.5	92.75	93.5		94.	
			A	94.5	94.	94.25	92.75	92.25	94.25	93.5	93.	93.5		93.4	
													Average,	92.6	33.7

walls the movement thought best to secure good contraction of the abdominal muscles, without the diaphragm, when compiled, located a very definite area at the posterior part of the side of the head. The base of this area extended along a line drawn from about 1 cm. above the occipital protuberance to a point 1 cm. above the meatus

auditorius. The area itself, 3–4 cm. wide, extended from the anterior surface of the psoas and iliacus area forward to a point 2.5 cm. above and behind the ear, which is just above the mastoid process. The rises of temperature in this area were very large, and very constant in their situation.

Contraction of the erector spinæ group, which are in some sense the antagonists of the previous group, caused elevations of temperature in the area lying in front of the psoas and iliacus area, and between the area for the flexors of the leg on the thigh and the abdominal area just laid out. The means used to bring about contraction of this group was to have the subject sit on the edge of a chair, lean against its back, and then make extension on the lumbar spine, causing a condition of partial opisthotonos. This must be an extension of the spine on the pelvis only, otherwise the glutei or the thigh flexors will act.

Elevations of temperature in this region were seen in a few instances to follow contractions of the gluteal group, but there is doubt whether these were not due to contraction of the leg on the thigh, an almost invariable accompaniment in movements which call the glutei into action.

THE FACE.

The study of the effect of contraction of the facial muscles was one of the first undertaken. In these experiments the thermometers were grouped on the opposite side of the head and then unilateral facial movements, as winking and retraction and elevation of the angle of the mouth, were made with the result of finding that a constant elevation of temperature took place on the side opposite the movements. Occasional rises occurred, however, on the same side, and these were inexplicable until it was discovered that they were caused by contractions of the occi-

pito-frontalis and attollens aurem over which the thermometers happened to be. Muscular contraction being well known to cause local elevation of temperature, this source of error must be guarded against in all experiments on the head and face. After being satisfied that in these, as in other, experiments a rise of temperature occurred only on one side, all observations were restricted to the side of the head opposite to the muscles involved. An attempt was made also to find areas for the different facial groups which can be contracted singly. To succeed in this the subject must have considerable power over his facial expressions, especially if unilateral movements are required. In all experiments unilateral movements are better, as activity of the side on which the thermometers are placed, is very apt to be misleading.

The first experiments were on the effect of retraction of the angle of the mouth, (buccinator, risorius, etc.,) and winking with the eye of the same side (orbicularis palpebrarum). These movements invariably produced a rise of temperature on the opposite side of the head about 9 cm. above the external auditory meatus. After a great many of these general experiments were performed, attempts at analyzing the facial area were made. (See Tables on p. 158 and 159.)

Contraction of the platysma myoides, in the subject a very powerful muscle and obedient to his will, produced constant elevations of temperature in an area about 3 cm. long and 2 cm. broad, and situated 7.5 cm. above and a little behind the auditory meatus. The rises of temperature seen here ranged from .25° to 2.5° F., many large ones being seen.

In a small area above the front part of this region, rises of temperature were recorded after spasm of the orbicularis oris, while farther back above the posterior part of the platysma region, is a space which experimentation shows to

belong to the retractors of the angle of the mouth, (buccinator, etc.,) while higher, rises of temperature are seen, probably caused by the elevators of the angle of the mouth. Spasmodic contraction of the orbicularis palpebrarum alone (winking) caused a rise of temperature in a small district located above the buccinator area and slightly back of the same. Although not a very strong muscle pretty constant results were obtained, rises of over a degree F. being many times noted after its contraction. The fact of this being its location was rendered still more plausible by finding, pretty near by, the centre for ocular movements now to be described.

The movements made use of to locate the ocular area were general in their character, vertical, lateral, rotatory, accommodative, etc., etc.

As a result of these experiments, which sometimes produced intense weariness and vertigo in the subjects, quite a large region was marked out where subsequent elevations of temperature took place.

This area was situated in the lateral, posterior parietal region, about 8 cm. vertically distant from the point 24.5 cm. on the median line. This places it in the small space left between the flexors of the leg on the thigh, and the extensors of the hand and fingers on the forearm. It is also seen to be in close proximity to the area for the orbicularis palpebrarum. The knowledge of the location of this area may be of great use in studying the physiology of conjugate deviation of the eyes. Several experiments have been performed to that end with, as yet, no conclusive result. The investigation will be continued and the results published later. (See Table on p. 159.)

The area for the tongue has already been referred to. It lies above and in front of the orbicularis oris about 10 cm. from the meatus. It is contiguous to, if not identical

with the area for the hyoid group of muscles already described.

The only important group of muscles left are those of mastication, (masseters, pterygoids, temporals). These

Date.	Muscle.	Area.												Average F.	Average C.
Jan. 30.	Tongue.	Lateral	B	89.75	89.25	90.5	91.	89.5	93.5	90.75	91.25	92.5		91.	
		Parietal	A	90.25	89.5	91.	91.5	90.	93.75	91.25	91.75	92.75		91.3	
Feb. 1.	"	"	B	92.	93.	93.	92.25	92.25	93.5	93.75	94.	93.75		93.1	
			A	93.	93.75	93.	93.	94.	94.	94.	94.25	93.75		93.6	
" 11.	"	"	B	92.75	92.	91.75	91.	92.	93.25	92.	91.5	93.		92.1	
			A	93.	92.5	92.	92.	92.5	94.	92.25	92.	93.5		92.7	
" 14.	"	"	B	94.5	94.	94.5	92.	93.	95.	93.	94.	95.		94.1	
			A	94.75	94.5	94.5	92.5	93.75	95.25	93.5	94.25	95.25		94.2	
" 17.	"	"	B	94.25	93.75	93.75	93.75	93.	93.	93.25	93.25	93.25		93.4	
			A	94.75	94.25	94.	93.75	93.5	93.5	93.25	94.	93.5		93.8	
" 19.	"	"	B	93.	94.	93.75	94.	94.5	94.25	94.	94.5	95.25		94.1	
			A	93.75	94.5	94.	94.25	95.	94.5	94.25	94.75	95.5		94.5	
" 22.	"	"	B	91.5	90.25	93.25	91.	93.	91.75	92.5	93.	93.		92.1	
			A	92.	91.	93.25	91.25	94.5	92.5	93.	93.5	93.		92.8	
Jan. 29.	Hyoids.	"	B	92.	92.	93.25	92.	91.5	91.	93.	93.5	93.		92.3	
			A	93.	92.75	93.75	92.25	91.25	91.75	94.	93.75	93.25		92.8	
Feb. 14.	"	"	B	93.	92.5	93.5	90.	92.	94.	92.	93.	94.5		92.7	
			A	94.5	94.	94.5	92.	93.	95.	93.	94.	95.		93.9	
" 1.	Artic.	"	B	93.	93.75	93.	93.	94.	94.	94.	94.25	93.75		93.6	
	m'v'm'ts		A	93.25	93.75	93.	93.	94.	94.	94.	94.5	93.75		93.7	
" 12.	Masseters	"	B	95.	95.25	95.	93.75	93.75	94.5	95.	95.	94.5		94.5	
	Orbic.		A	95.5	95.75	95.5	94.	94.	95.5	95.5	95.5	95.		95.1	
Jan. 24.	palp.	"	B	92.	92.5	92.5	92.25	93.25	91.25	91.5	91.25	91.25		91.9	
			A	92.5	93.	93.	92.75	93.5	91.25	91.75	91.25	91.25		92.	
Feb. 1.	"	"	B	92.	90.5	90.25	91.	93.	93.	93.	92.75	94.5		92.3	
			A	93.	92.	91.	92.	93.75	93.5	93.25	93.	94.75		93.	
" 3.	"	"	B	86.	84.	87.5	85.5	88.5	86.	86.	83.	83.		85.1	
			A	86.5	85.	87.75	85.	88.5	86.	86.5	83.25	84.5		85.9	
" 5.	"	"	B	91.5	91.75	93.5	92.	93.	92.25	92.5	91.	92.		92.1	
			A	92.	92.25	94.	92.75	93.75	92.75	93.	92.	92.75		93.	
Jan. 1.	Face.	"	B	92.	90.25	90.25	88.5	89.75	89.	91.	92.75	89.		90.7	
			A	93.	92.	91.75	88.5	90.25	92.	91.5	92.5	91.5		91.5	
" 4.	"	"	B	93.75	92.5	91.5	90.25	90.5	90.5	91.75	91.5	91.	90.5	91.3	
			A	94.5	94.5	93.5	94.	94.	93.	91.5	91.	92.	91.5	92.9	
" 9.	"	"	B	92.25	92.75	93.	93.25	93.5	92.75	92.5	92.25	92.	93.5	92.8	
			A	92.5	92.75	92.5	92.5	93.25	92.	92.25	92.	92.5	93.25	92.5	
" 12.	"	"	B	95.5	95.75	95.5	94.75	95.25	95.25	95.25	95.25	95.5	95.25	95.3	
			A	95.5	95.75	95.5	94.75	95.25	95.25	95.25	95.25	95.5	96.	95.3	
" "	"	"	B	94.25	94.75	95.	94.	94.	94.5	94.75	94.25	94.5	95.	94.5	
			A	94.5	94.75	95.	94.5	94.5	94.5	94.75	94.75	94.5	95.	94.7	
" 13.	"	"	B	91.25	91.75	92.5	91.	92.	92.5	91.25	92.5	91.5	92.	92.	
			A	90.	91.5	92.25	90.	92.25	92.75	90.75	91.75	92.	92.25	91.6	
" 14.	"	"	B	92.25	91.75	90.5	91.75	93.25	92.5	91.5	92.75	91.75	91.25	92.	
			A	92.25	91.75	91.5	93.75	93.25	92.5	91.5	93.25	91.75	91.25	92.6	
" 4.	"	"	B	94.75	93.5	93.75	93.25	93.25	92.5	92.75	93.5	93.	93.	93.8	
			A	93.75	93.75	94.	93.	92.25	93.	93.5	94.	93.	93.75	93.7	
" 29.	"	"	B	91.	92.	92.5	91.75	90.5	92.5	91.25	92.75	89.75		91.5	
			A	92.	92.	92.5	92.25	90.5	92.5	92.75	92.75	89.75		92.	
" 30.	"	"	B	89.	88.5	89.75	90.25	89.	93.	90.	90.5	92.25		90.2	
			A	89.75	89.25	90.5	91.	89.5	93.5	90.75	91.25	92.5		90.7	
Dec.	Face.	Negro.	B	92.75	94.	94.5	93.5	91.75	94.25	93.25	92.75	94.25	93.5	93.8	
1879			A	93.25	94.25	94.5	93.75	92.5	94.25	93.5	92.75	94.5	94.25	94.1	
"	"	"	B	92.75	94.25	94.25	93.5	93.25	94.5	91.75	92.75	93.5	94.	93.8	
			A	92.75	94.5	94.25	94.25	93.5	94.5	92.5	93.25	93.75	94.25	93.8	
"	Miscel-	"	B	93.25	94.	94.5	93.25	94.5	93.75	93.75	95.	94.25	94.5	94.5	
	laneous.			92.	93.5	93.25	92.5	93.75	93.25	92.75	94.25	93.25	93.75	93.5	
"	"	"		92.	93.75	93.25	94.	92.75	93.5	93.25	93.5	93.5	93.75	93.7	
"	"	"		92.75	93.25	93.	94.5	93.75	92.	93.5	94.75	94.	92.75	93.4	
				93.25	93.25	91.75	93.25	93.25	94.5	93.				93.1	
				92.75	94.	94.25	93.5	93.75	94.	93.75	94.			93.8	
													Average,	92.8	33.8

being exceedingly strong muscles, one would think it very easy to locate them, but the reverse is the case. Two causes prevent their easy localization ; one is the fact that they cannot be contracted unilaterally, and the second is that their areas are in all likelihood situated directly underneath the very muscles, (temporals), which when active themselves, develop a large amount of heat. Temperatures taken

DATE.	MUSCLE.	AREA.												Average F.	Average C.
Jan. 22,	Retrac-	Lateral	B	89.75	92.	91.5	89.5	91.	89.5	89.25	88.5	89.5		90.	
1880.	tion of	parietal	A	91.	92.	90.75	91.	90.25	90.75	90.5	88.5	89.25		90.4	
Jan. 27.	angle	"	B	93.5	93.25	93.5	92.5	92.	91.5	92.25	92.25	92.		92.5	
	of mouth.		A	93.75	93.75	93.75	92.5	92.	91.75	92.5	92.75	91.75		92.7	
Feb. 1.	"	"	B	93.	92.	91.	92.	93.75	93.5	93.25	93.	94.75		92.7	
			A	93.	92.	91.	92.	93.75	93.75	93.5	93.	94.75		92.9	
" 4.	"	"	B	92.	93.	93.5	93.	92.	94.5	92.	92.	93.5		92.8	
			A	92.25	93.25	94.	93.25	92.	95.	[illegible]	92.5	93.5		93.	
" 10.	"	"	B	92.75	91.75	91.25	89.	92.25	94.	92.75	93.	92.5		92.1	
			A	93.	91.75	91.25	89.	92.25	94.	92.75	93.	92.5		92.	
" 19.	"	"	B	92.25	91.5	92.	93.	94.5	93.5	93.75	94.	94.25		93.1	
			A	92.5	92.25	92.5	93.25	94.75	93.75	93.75	94.	94.25		93.4	
" "	"	"	B	92.5	92.25	92.5	93.25	94.75	93.75	93.75	94.	94.25			
			A	93.	92.25	92.5	93.5	95.	94.	93.75	94.	94.5		93.6	
Jan. 1.	Orbic.	"	B	92.	93.25	92.5	93.	93.	92.75	91.5	91.	92.25		92.3	
	oris.		A	92.	93.5	93.	93.	93.	93.5	92.	91.25	92.5		92.6	
" "	Platysma	"	B	92.	93.5	93.	93.	93.	93.5	92.	91.25	92.5			
	Buccin.		A	94.	93.5	93.25	93.	93.	93.5	92.5	91.5	92.75		92.7	
" 22.	Platys.	"	B	89.75	92.	91.5	89.5	91.	89.5	[illegible]	88.5	89.5		90.	
			A	89.	91.25	90.25	90.	91.5	91.5	87.5	88.25	90.25		89.	
" 24.	"	"	B	91.	92.	92.25	91.	91.25	90.5	91.	91.	90.5		91.1	
			A	92.	92.5	92.50	92.25	93.25	91.25	91.5	91.25	91.25		91.9	
" 27.	"	"	B	93.	92.75	93.	92.	91.25	91.5	92.	92.	92.		92.1	
			A	93.5	93.25	93.5	92.5	92.	91.5	92.25	92.25	92.		92.5	
" 29.	"	"	B	92.	92.25	91.75	92.25	90.75	91.	92.	91.75	92.5		91.5	
			A	92.75	92.	92.5	92.5	91.5	93.5	92.	92.75	91.5		92.3	
" 30.	"	"	B	92.	92.	92.	92.	90.5	92.75	92.	91.25	93.5		92.	
			A	92.5	92.5	92.75	92.5	91.	93.	92.	91.75	93.5		92.2	
Feb. 10.	"	"	B	93.	91.75	91.25	89.	92.25	94.	92.75	93.	92.5		92.1	
			A	93.	92.	91.5	89.25	92.5	94.	92.75	93.25	92.5		92.3	
" 16.	"	"	B	93.	92.5	92.	92.	92.5	94.	92.25	92.	93.5		92.6	
			A	93.	92.5	92.5	92.	92.5	95.	92.25	92.	93.5		92.8	
" 1.	Occip.	"	B	93.	92.	91.	92.	93.75	93.75	93.5	93.	94.75		92.7	
	Front.		A	93.	92.	91.	92.	93.75	93.75	93.75	93.25	95.		93.	
Jan. 1.	Eyes.	Poster'r	B	89.75	88.5	89.	90.	89.5	90.25	89.5	89.	90.		89.5	
		parietal	A	90.75	89.	90.	90.5	89.75	91.	90.5	91.75	91.25		90.5	
" "	"	"	B	81.75	88.75	90.	87.75	89.	87.	87.5				88.5	
			A	81.75	88.	88.75	85.75	88.5	87.	89.				88.	
" 2.	"	"	B	90.5	91.	92.75	92.5	91.25	89.5	90.5	90.	91.	91.75	91.	
			A	91.75	91.	91.5	92.	90.5	91.25	90.5	90.75	91.25	89.75	91.1	
" "	"	"	B	91.	91.5	92.25	91.75	92.25	92.	92.	92.	91.75	91.	91.7	
			A	91.75	92.75	92.25	91.5	92.	92.25	92.	92.5	91.75	91.5	92.2	
" 3.	"	"	B	88.5	92.	91.	92.75	92.	88.5	90.75	90.5	86.25	91.75	90.4	
			A	86.5	92.5	91.	92.	91.75	90.	90.75	90.5	84.5	91.25	90.	
" 31.	"	"	B	90.75	88.25	88.5	90.5	88.75	88.75	90.5	89.	91.		89.4	
			A	90.	89.75	88.75	90.5	90.25	88.75	90.25	88.5	90.5		89.7	
Feb. 3.	"	"	B	92.	91.75	91.75	93.	91.	92.	92.75	92.	92.25		92.	
			A	92.25	93.75	93.	93.5	92.	93.5	93.5	92.75	92.25		92.9	
" 17.	"	"	B	93.5	94.25	94.25	94.	93.25	93.75	92.5	93.5	94.5		93.7	
			A	93.25	94.	94.5	93.75	94.5	93.75	93.25	93.5	94.5		93.9	
													Average,	92.8	33.8
Averages of all Temperatures taken, about 3,000 in number. . . .														92.4	33.6

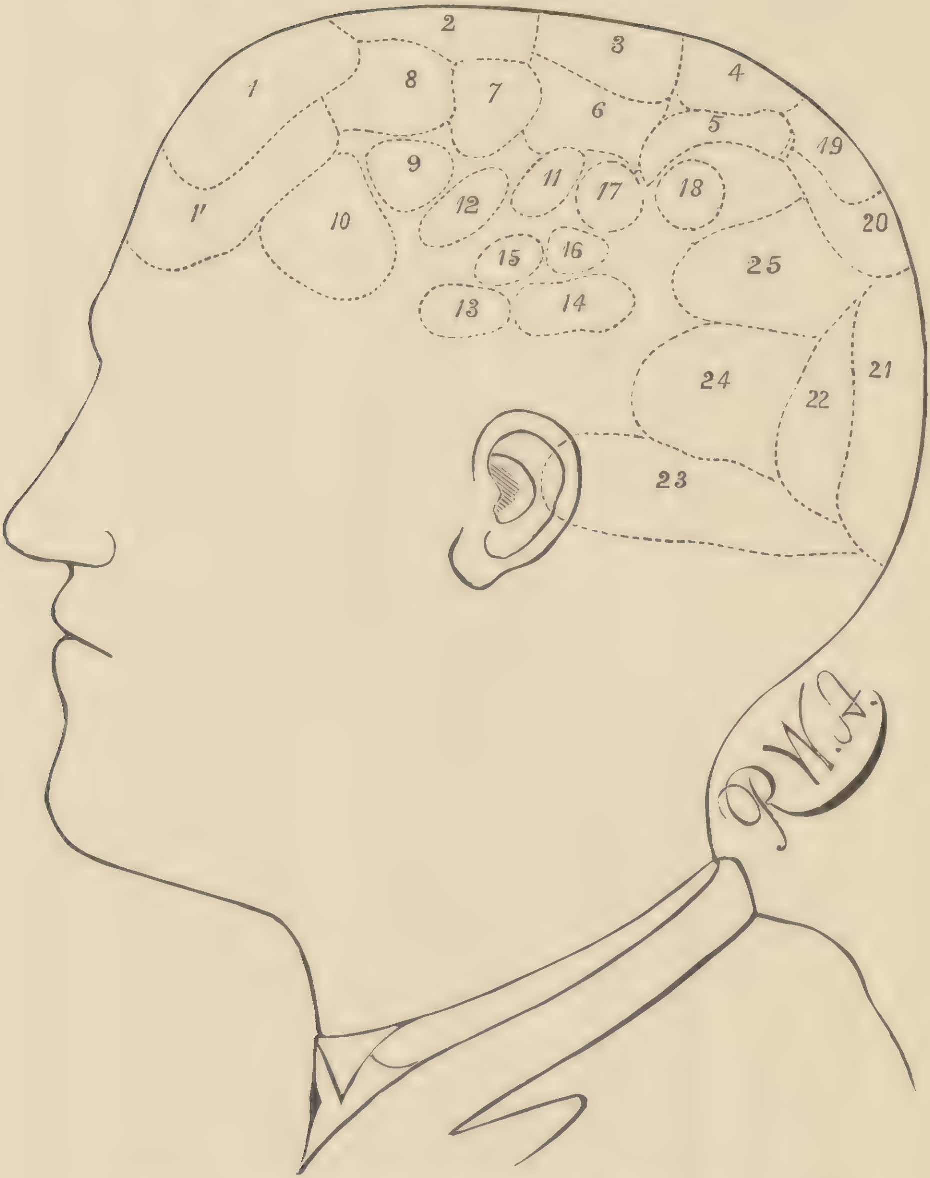

FIG. 5.—Outline of the head of the first white subject, with all areas mapped out. Explanation on p. 161.

FIG. 5.—1. Trapezius and levator anguli scapulæ, probably middle part of the trapezius and rhomboids, (elevation, retraction and depression of shoulder).

2. Deltoid, (abduction of the arm).

3. Biceps, (flexion and supination of the forearm, hence probably near or in this space belongs the area for the brachialis anticus).

4. The triceps, (extension of the forearm).

5. Extension of the hand and fingers, also interosseii.

6. Flexors of the hand and fingers, (also probably between this area and and 3, a space for the supinator longus).

7. Latissimus dorsi, (depression and retraction of the shoulder aside from the trapezius.)

8. Pectoralis major and perhaps part of serratus magnus, (adduction of arm and depression—forward—of the shoulder).

9. Complexus, trachelo-mastoid and other deep extensors of the head and neck.

10. Scaleni, recti antici, etc , (bending the neck forward).

11. Elevation of the angle of the mouth.

12. Tongue, and hyoid group.

13. Sterno-mastoid.

14. Platysma myoides.

15. Orbicularis oris.

16. Buccinator, etc., (retraction of the angle of the mouth).

17. Orbicularis palpebrum.

18. Ocular muscles, recti and oblique.

19. Anterior tibial group, (flexion of foot, on the leg, and extension of the toes).

20. Calf group of muscles, (extension of foot, on the leg and flexion of the toes).

21. Quadriceps extensor femoris, rectus and vasti, (extension of the leg on the thigh).

22. Psoas and iliacus, (flexion of the thigh on the abdomen).

23. Abdominal muscles, (retraction of the abdominal walls).

24. Erector spinæ, etc., (partial opisthotonos).

25. Biceps, semi-membranosus and semi-tendinosus, (flexion of the leg on the thigh).

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in this region and elsewhere show marked variations, but the fact that a thermometer, placed on the opposite masseter muscle during the experiment, showed a rise of 2.76° F. rendered these results uncertain. The region, which will undoubtedbly be located soon, is very probably in the lateral parietal region, about 6.5–7.5 cm. above and in front of the meatus.

Thus far it will be observed our efforts have been directed solely to the mapping out of circumscribed areas on the scalp in which constant elevations of temperature occur after willed activity of certain muscles or groups of muscles. No mention has been made of the relations these areas bear to the subjacent convolutions. The latter will be the subject of the next chapter, while this will close

with a brief summary of the results of the foregoing experiments, the accompanying figure showing the muscle areas as marked out on the graduated head. (See p. 160-161.)

CORROBORATIVE EXPERIMENTS ON OTHER SUBJECTS.

For reasons given before it was thought best to confine almost all experiments to one subject, and, after it was proven that the rises of temperature following unilateral movements were unilateral, to confine observations to the opposite side of the head.

Most of the temperatures, from which the foregoing conclusions were reached, were hence taken on the left side of one subject's head. Corroborative experiments were made on the opposite side of his head, and on the head of a second white subject, and a negro, both adult males.

The muscles experimented on in the white subject, were the right triceps and quadriceps femoris.

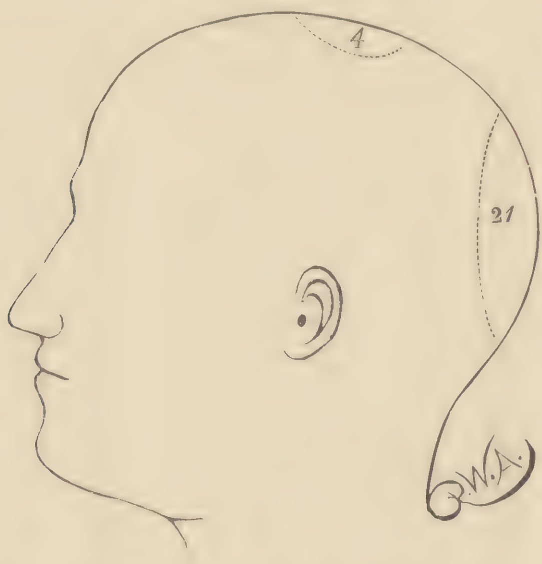

FIG. 6.—Outline of the head of the second white subject with areas of his triceps, (4), and quadriceps, (21).

On account of the thickness of the hair in the subject, the rises of temperature were not large, but still they were marked and located as in areas 4 and 21, Fig. 5.

Their location is shown in the appended figure.

The negro, selected on account of his well-shaped head and close-cut hair, proved almost useless as a subject because, although intelligent, it was hard to teach him to contract but one muscle at a time, and he could not be left quiet but a few minutes at a time without going to sleep.

This latter habit, which may have been the prodromic stage of the sleeping sickness of his fatherland, although annoying, beautifully demonstrated one fact, however, and that was that with the outset of sleep there was a general

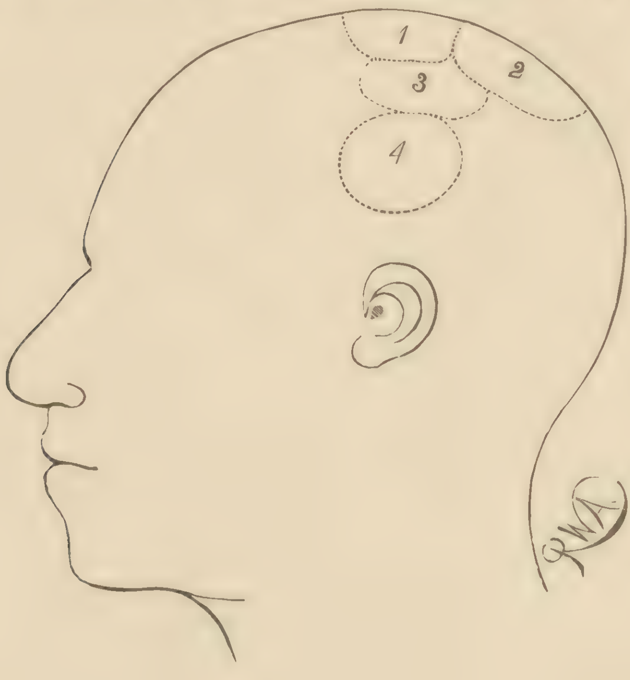

FIG. 7.—Outline of negro's head with areas: 1, face; 2, leg; 3, arm; 4, forearm.

fall of his cranial temperature of about a degree Fahrenheit. This was demonstrated on several occasions.

The muscles experimented on in the negro were the facial, arm, forearm, and leg groups. These experiments were on different sides of the head, but for simplicity they are all shown in the following outline of the left side of the head. The areas as marked out, corresponded very nearly to areas for the arm, forearm, face and leg in figure 5.

The movements used to attain these results were the same as in the former experiments.

THE APPLICATION OF THE RESULTS OF THE FOREGOING EXPERIMENTS TO THE STUDY OF CEREBRAL LOCALIZATION.

Had it been possible, at the end of these experiments, to have killed the subject, and to have compared the external areas with the subjacent convolutions, as they who experiment on dogs and monkeys can do, the task would have been easy, and the result definite. This being impossible, however, it will be necessary to call in the aid of craniocerebral topography, so ably worked out by others, and by it look through the cerebral envelopes at the cortex itself. This will be done as follows: First, in a full-sized outline of the head insert an outline of a properly fitting skull, with its sutures (the location of which can be made out on most living heads); then inside the skull outline the convolutions and fissures of a normal brain, and over all trace in broken lines the muscle areas as marked out on the surface of the head.

Such is the construction of the adjoined plate. In order to preserve clearness of outline, all attempts to represent the perspective of the head, as lines, shading, etc., have been omitted, and unless the distance between the superficial areas and the cortex is carefully reckoned, the plate will be apt to mislead. To explain more fully: the super-

ficial areas are distant 1.–1.5 cm. from the cortex, being separated by hair, scalp, skull, dura mater and inter-meningeal space. This distance may be neglected when looking at those parts of the head lying at right angles to the line of vision. When the areas near the periphery are looked at, however, this separation of the two planes makes the superficial area seem farther from the eye than the corresponding area of the cortex.

FIG. 8.—Outline of a normal human brain, taken with Broca's stereograph, and reduced one-half, to which the external motive areas have been transferred (numbers the same as in Fig. 5.)

This discrepancy increases as the periphery is approached, and some of the areas near the median line seem wholly beyond the brain substance. To project them properly on the cortex, one must study the position they would assume if dropped perpendicularly on the subjacent convolutions.

This has been carefully done in Fig. 8, appended.

The part of the brain underlying the trapezius area is thus seen to be the anterior part of the first frontal convolution. Further back on the same comes the deltoid, and further still the biceps area, while that of the triceps probably overlaps to a slight degree the fissure of Rolando. The area for the scaleni, etc., will fall on the second frontal convolution, in front of its middle; the deep extensors of the neck on the second frontal convolution near its middle. The pectoralis area will fall on the middle of the second frontal convolution, slightly overlapping the superior frontal sulcus. The area for the latissimus dorsi occupies a similar position farther back.

The point of junction of the superior and ascending frontal is occupied by the hand and finger flexors, while lower on the ascending frontal lies the area for the elevators of the angle of the mouth, and lower still the orbicularis oris in front of and above which is the area for the tongue and hyoids, which lies on the third frontal convolution. At the base of the ascending parietal convolution, but reaching a slight distance across the fissure of the Rolando, lies the platysma area, higher the area for the orbicularis palpebrarum, and higher still, lying partly on the ascending parietal, and partly on the ascending frontal convolutions, is the area for the extensors of the hand and fingers.

The anterior part of the superior parietal lobule holds the anterior tibial area, behind which lies that of the calf.

On the posterior part of the superior parietal lobule, but falling chiefly on the first and second occipital gyri is found

the area for the quadriceps extensor femoris, while on the third occipital gyrus and the posterior part of the inferior middle temporal lobule will fall the area for the abdominal muscles. On the posterior parts of the angular gyrus and middle temporal lobule will fall the psoas and iliacus area. The rather indefinite area marked out for the erector spinæ overlies about equally the posterior part of the upper and middle temporal lobules, while higher up over the contiguous portions of the angular and supra-marginal gyri, and the superior temporal lobule is the area for the flexors of the leg on the thigh. On the upper part of the supra-marginal gyrus will fall the area set apart for ocular movements.

This transference of the motor areas from the scalp to the brain leaves but little of the cerebral convexity uncovered, viz., the anterior half of the temporo-sphenoidal lobe and the extreme anterior frontal region.

SIGNIFICANCE OF THE EXTERNAL MOTOR AREAS.

The question now arises, what these areas, as marked out on the surface of the head, are. What can they be but the outward representation of psycho-motor centres in the cerebral cortex? To revert to the propositions laid down at the outset. All will agree, first, that the psycho-motor centres, for some groups of muscles, are located in a certain definite part of the cortex, and, second, that changes of temperature in the cerebral cortex, when marked, are indicated by surface thermometers. If, after willed activity, then, of a certain muscle, a rise of temperature occurs in a small area of the scalp, which is known to directly overlie the cortical centre for that muscle, and nowhere else, it is natural to attribute the rise of temperature on the scalp to a larger rise of temperature in the subjacent motor centre. If, now, with contraction of a different muscle, there occurs

a rise of temperature in an equally definate area in some remote part of the head, what is more natural to think that this too is caused by the functional activity of a subjacent psycho-motor centre, even if its location does not harmonize with the accepted theories on the subject?

The question naturally arises, were not some of the large elevations of temperature noticed by Lombard in his experiments on the effect of mental states, and by Gray in his lecture, due largely to muscular action? Some of the large rises in Gray's cases were situated over the facial and arm centres, which must necessarily be active during a spirited lecture, especially if the lecturer gesticulate much.

A further proof of this theory is the striking similarity between the centres marked out by thermometry and those of Ferrier (compare Figs. 2 and 5).

This similarity is particularly marked in the leg, arm, forearm and facial centres in both diagrams.

Compare, for instance, the functions he attributes to his single area, 2, 3, 4, and the functions given to the areas, 3, 4, 19 and 20 in Fig. 5. Ferrier's circles, *a*, *b*, *c* and *d* occupy much the same locality as centres 5 and 6 in Fig. 6. His 7 and 8 correspond pretty well to 11 and 16 of Fig. 8. His 9 and 10 to the 12 and 15 of Fig. 8. His 11 is almost exactly covered by 14, Fig. 8. His circle 12 would include, among others, the centre 9, Fig. 8. His centre 5 corresponds pretty well to area 2, Fig. 8, while his 1 would cover a part of the areas 19, 20 and 21 in Fig. 8. His circles 13, 13^1 fall somewhat below the area 18, Fig. 8.

A careful comparison of the functions attributed to the corresponding parts in the two figures is particularly interesting.

It will be seen, however, that centres are more closely analyzed in Fig. 8 than in Ferrier's chart. It will also be seen that a great many centres are added to his list in Fig.

8, and regions of the brain hitherto considered psychical or sensory have been peopled with psycho-motor centres. This fact, it is known, will receive some severe criticism, and it will be asked how can the centre for the trapezius, for instance, be located on the frontal lobes, destruction of which has been known to cause no paralysis? The answer to this question is two-fold: In the first place, look to Ferrier again. The point at which he locates the centre for the "extension forward of the arm and hand, as in putting forth the hand to touch something in front," corresponds to the area 2 and part of 8 in Fig. 8, which are allotted there, to the deltoid and pectoralis major, the two muscles which, *par excellence*, are involved in this movement. Again, his large area 12, "a centre for lateral movements of the head and eyes," lies largely on the middle of the first frontal convolution, where in Fig. 8 lies the trapezius, a very strong muscle in head movements.

In the second place, when a case is forthcoming in which the absence of *all* paralysis can be proven, then it will be time to retract.

When the surgeon stands at the bedside of a patient who has received a destructive wound of the frontal lobes, or when a physician examines a semi-comatose subject, suspected of having a cortical lesion in the same location, what is done? The patient is asked to move his hand and fingers, which he does, his forearm, which he flexes and extends, and perhaps (although rarely) he may be asked to abduct the arm, which also is possible. As an extra refinement, a dynamometer may be thrust into his hand, and he may squeeze 20–40 kilogrammes.

Death ensues, an autopsy is made, and the case is published as one of destructive lesion of the frontal lobes without paralysis.

Might not a closer examination have revealed the fact

that the power of shrugging or retracting the shoulder was lost or weak (trapezius), or that the power of extending the arm and shoulder forward was diminished (pectoralis major), although perhaps the arm could still be abducted (deltoid), or still, again, some impairment in head movements (trapezius, rotators, extensors, scaleni, etc., etc.)?

When these symptoms are looked for and not found, and destruction of the areas 1, 8, 9 or 11, Fig. 8, are demonstrated, then will be the time to reconsider the statements in the preceding pages.

Destruction of cerebral substance, especially traumatic, is so often accompanied by mental obscuration or coma as to make a strictly scientific examination very difficult.

Again it will be said, how explain those cases of complete hemiplegia where only a small lesion, seemingly involving only one of the small areas laid down in Fig. 8 exists?

The reply is a question. Is the anatomy and physiology of the centrum ovale sufficiently well known to trace exactly all commissural and radiating fibres to their cortical terminations, or to show what effect a superficial cortical lesion has on the subjacent white matter?

If such is not the case, may not, perhaps, some fibres of the corona radiata originating in the occipital lobes join the motor tract, or may not a small cortical centre, which is the seat of a lesion, by its commissural connections, be able to arrest the functions of its fellows?

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